



The Blast Furnace and Steel Plant

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The Blast Furnace *and* Steel Plant

VOL. IX.

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No. 7

Electric Motor Drive for Traveling Cranes

A General Discussion of Electric Motor Drives for Cranes—The Question of Manual vs. Magnetic Control for Cranes Is Thoroughly Discussed.

By GORDON FOX,
Electrical Engineer, Freyn-Brassett & Co.

PART I.

THE electric motor is particularly adapted as a source of power for cranes, due to its small size and weight, its ready control, and the relative ease and efficiency with which electric power may be transmitted to the moving elements of the crane. The great majority of cranes are therefore electrically driven.

Cranes are built in a great variety of forms. The most common form is the overhead traveling crane. Gantry cranes find frequent application, particularly for outside work. The gantry crane, as represented by the ore and coal handling bridges, reaches very large proportions. Among the more special types may be mentioned soaking pit cranes, stripper cranes and chargers having rigid hoists and revolving types, such as locomotive and ship building cranes. This discussion will deal primarily with the more common types, the principles of which apply, with some modification, for all types.

Cranes may be classified also as to the nature of the service. A power house crane serves primarily for erecting and repair work. It makes heavy lifts at slow hook speeds, occasionally, and has long periods of rest. A mill or shop crane covers a variety of work, most of the lifts being below rating. The service is more or less intermittent. The speeds are intermediate. A material handling crane, such as a loading crane, yard crane, magnet handling crane or bucket handling crane, generally makes regularly repeated lifts, often near rated capacity. High speed is desirable or perhaps of first importance.

The function of the electric motor is to supply torque, power and motion to the crane elements. The crane elements are the hoisting mechanisms, the trolley traverse and the bridge travel. The hoist consists of one or more drums, driven through gearing from one or more motors. In the more common case one motor drives through two or three reductions to the drum. Ladle cranes are frequently equipped with two motors driving two drums, which are geared together. Bucket handling cranes usually carry two lines, a holding line and a closing line. These are carried on two drums which may be driven by individual motors. In some designs one motor is used, the closing line drum being geared directly to the motor, the holding line drum being driven through a clutch, which is air operated.

The hoisting speed of a crane depends upon the hoist-

ing distance, the nature of the load and the service. A standby crane, such as a power house crane, may well have very low speeds because speed is not essential and precision is important. Moreover, low hoist speeds permit relatively small hoist motors. The investment in a standby crane may well be minimized by gearing for low speeds. Ladle cranes are operated at low speed as the hoisting distance is small and safety paramount. Heavy lifts may well be arranged for slow speeds, where permissible, as influencing the size of hoist motors and mechanisms, which are necessarily large and heavy. General service cranes are equipped for moderate speed hoisting. In this service particularly, the series motor characteristic is admirable in that the lighter work is done at higher speeds. Bucket and magnet cranes and material handling cranes in general are arranged for high speed hoisting. The extreme case is the ore and coal handling bridge which may hoist 100 feet or more, each trip. The following speeds are suggestive of existing practice:

Hoisting Speeds.		
Type of Crane	Capacity	Hoisting Speed
Hand operated.....	1 to 5 tons	1 ft. per min.
Standby.....		10 to 25 ft. per min.
Ladle crane.....	100 to 150 tons	10 to 15 ft. per min.
Mill service.....	5 to 15 tons	25 to 60 ft. per min.
Mill service.....	20 to 50 tons	15 to 30 ft. per min.
Foundry.....	5 tons	40 ft. per min.
Foundry.....	10 tons and above	12 to 25 ft. per min.
Auxiliary Hoists....		25 to 60 ft. per min.
Skull cracker.....	5 to 15 tons	80 to 120 ft. per min.
Ore bridge.....	5 to 10 tons	200 to 600 ft. per min.

The work done by a crane hoist motor comprises the following items:

- To hoist load against gravity.
- To overcome friction of hoisting mechanism.
- To accelerate load, impart kinetic energy.
- To accelerate motor and mechanism.
- To retard load in lowering.
- To decelerate load in stopping.
- To decelerate motor and mechanism in stopping.

We will investigate the relative import and magnitude of these elements of load. The work of hoisting may be expressed by the simple formulae.

$$T_h = \frac{W}{2\pi N_e}$$

$$HP = \frac{T_h \times 2\pi \times \text{rpm}}{33000} \text{ or } HP = \frac{WV}{33000 \times e}$$

T_h = motor torque to hoist load, foot-pounds.

W = weight of hook and load, pounds.

V = hoisting speed with load W , ft. per minute.

N = rev. of motor per foot hook travel = $\frac{\text{rpm}}{V}$

e = efficiency of gearing, decimal.

The friction losses in a crane hoist occur in the gearing and shaft and drum bearings, sheaves and cable bending. Each reduction introduces losses of 7 to 10 per cent. The hook, sheave and cable losses are about 3 to 5 per cent. Small, high speed cranes are usually the more efficient, having less mechanism. Their overall efficiency may reach 75 per cent whereas larger cranes will ordinarily have efficiencies between 60 and 70 per cent.

The following formulae apply to the acceleration of the hook and load of a crane.

$$T_a = \frac{W}{\frac{G \times A}{2\pi N e}}$$

$$HP = \frac{T_a \times \frac{\text{rpm}}{2\pi \times 2}}{33000} \text{ or } HP = \frac{W \times A \times \frac{V}{2}}{33000 \times e}$$

T_a = motor torque to accelerate load—foot-pounds.

G = acceleration due to gravity = 32.2.

V = velocity at end of acceleration period, ft. per min.

$\frac{V}{2}$ = average velocity during acceleration.

A = rate of acceleration—ft. per sec. per sec.

During the acceleration period, half the electrical input is consumed in resistance. The motor operates at reduced voltage and increased current. The heating of the motor is proportional to the current which, in turn is proportional to the input. Therefore, for determination of motor input and heating

$$HP \text{ (input)} = \frac{T_a \times 2\pi \text{ rpm}}{33000}$$

or

$$HP \text{ (input)} = \frac{W \times a \times V}{\frac{G}{33000 \times e}}$$

The rate of acceleration of crane hoists varies according to the service. The acceleration of an ordinary crane will not exceed 1 foot per second per second. A coal or ore bridge will accelerate at 1 to 5 feet per sec. per sec., 2 to 2.5 ft. per sec. per sec. being usual average figures.

A comparison of the formulae for hoisting and accelerating torques gives the following:

$$\frac{T_h}{T_a} = \frac{W}{\frac{W}{G} \times a}$$

Let $a = 2$ ft. per sec. per sec.

$T_h = 16 T_a$

It will thus be seen that the accelerating torque is a relatively small item, in hoisting except at high speeds,

600 ft. per min. and above. The torque and power necessary to accelerate the motor armature, brake wheel and revolving mechanism, may be expressed by the formulae:

$$T_m = \frac{W_r^2 \times \text{rpm} \times 2\pi}{G \times 60 \times t}$$

$$HP \text{ (input)} = \frac{W_r^2 \times \text{rpm}^2}{1613000 t}$$

T_{m2} = motor torque to accelerate motor and parts number feet.

W_r = moment of inertia of revolving parts at motor shaft number feet².

t = time to accelerate to rpm = $\frac{V}{a}$, sec.

In the ordinary case, the inertia of armature and hoisting mechanism proves to be a relatively small item.

The conditions in lowering depend upon the loading and upon the type of motor and control. As direct current motors with dynamic braking control are most common, they are selected for discussion. To lower a light hook the motor must exert power driving the hook downwards, since the weight of the hook is not sufficient to overcome the friction of the hoisting gear. At some fractional load, perhaps 5 to 15 per cent of rating, the load is sufficient to overcome hoist gear friction. The motor armature then merely floats on the line, taking little or no current. With higher loads the motor restrains the load, which is overhauling. Moreover, the armature current and the field current have different values, in lowering. It is therefore difficult to definitely evaluate the heating effect of the motor in lowering. The following approximations may be used:

To lower light hook:

$$HP = \frac{W \times V \times .10}{33000}$$

Where W = rated load—pounds.

V = lowering speed, feet per minute.

To lower an overhauling load:

$$HP = \frac{W \times V \times e}{33000}$$

Where W = weight of load—pounds.

V = lowering speed—feet per minute.

e = efficiency of hoisting gear, using same values as for hoisting.

In the case of a two motor, bucket handling hoist, the hoisting load may be considered as equally divided between motors. The closing load depends upon the bucket and condition of material but may be taken as half the hoisting load. The load in lowering may be taken as occurring 80 per cent on the holding line and 20 per cent on the closing line.

The determination of the size of the hoist motor for a crane is based upon its ability to develop safely sufficient torque to lift and accelerate the heaviest load which the crane may be expected to handle, together with heat dissipating ability to enable it to withstand successfully the service which will prevail. These two considerations may differ materially. Some cranes, such as bucket handling and yard cranes, may be expected to handle rated load regularly. For such cranes, considerations of heating will determine the motor selection. General service cranes handle an average load of about 25 per cent rating. Inasmuch as cranes are designed with some overload capacity, 25 to 50 per cent, the motor should have sufficient torque to handle such a load. It will then be capable of handling the normal load with ease.

The following method for hoist motor size selection is suggested. Determine the hp required for hoisting and accelerating, by the formulae given above. In determining this hp, use load and speed values corresponding to the crane capacity rating. For standby cranes the hp thus found may be made equal to the 15 minute hp rating of the motor selected. For general service cranes the hp rating as determined above should correspond to the 30 minute hp rating of the motor selected. For cranes operating upon regular cycles a motor should be selected whose 60 minute rating, or longer time rating for severe service, covers the hp requirements. For cranes of the latter class, a check on motor heating, as later described, is desirable.

The motor size having been determined, at least tentatively. The gear ratio between winding drum and motor may be found by the formula :

$$N = \frac{\text{rpm}}{V}$$

N = motor revolutions per foot hoist travel.
Where rpm = motor speed corresponding to hoisting hp with capacity load.
V = hoisting speed with capacity load, feet per minute.

Knowing N, the sheave arrangement and drum diameter, the gear reductions are determined. In selecting the hoisting speed and gear ratio for a crane equipped with a direct current series motor, the fact should be borne in mind that the crane will hoist the empty hook at 200 to 25 per cent rated speed. The average load for a general service crane is about 25 per cent capacity. The corresponding speed is 150 to 175 per cent rated speed with capacity load. The speed should be selected as most suitable for the average load, the rated speed being correspondingly lower.

The motor size and gear ratio being selected, it may be well, particularly in the case of the general service and standby cranes, to check the torque demanded to hoist the heaviest probable overload, to see that the motor will develop this torque with a safe overload current value.

In the case of the continuous duty loading crane, the motor selected should be checked as to heating. The best method for doing this is by comparing losses with heat dissipating ability. The method may best be illustrated by a typical case, involving the hoist motor of a bucket handling crane. The hp for the various movements have been determined as above and the time of each movement determined by comparison of distance and speed or by means of time distance curves based on velocity and acceleration values selected. A table may then be prepared tabulating the losses about as follows:

Seconds	Action	Output hp	Watts Loss From Curve	Watts Loss X Seconds
6	Close bucket ...	40	4,200	25,200
10	Hoist	80	10,400	104,000
3	Open bucket ...	30	3,500	10,650
10	Lower	45	4,650	46,500
16	Rest	0	0	
45				186,350

The values of watts loss corresponding to hp output are taken from motor manufacturer's curves. The total running time is 6 + 10 + 3 + 10 = 29 seconds. The average watts loss while running is $\frac{186350}{29} = 6420$.

From the motor curves it may be found that 6420 watts loss per second while running will not heat the motor above 75 degrees centigrade rise provided the running time is not more than 65 per cent of the total time. In

the above case the running time is $\frac{29}{45} \times 100$ or 64 per cent of the time. Therefore the motor will not overheat under this duty, continuously repeated.

In the above discussion, a series wound direct current motor with dynamic braking control was considered. Dynamic braking control is now used almost universally on direct current equipped cranes. However, for alternating current cranes, the practice varies. In the majority of cranes mechanical load brakes are supplied. In lowering, the motor drives downward against the retarding effort of the load brake. In some ac cranes of special types, the lowering is done by friction brakes, independent of the motor. In some of the larger installations such as coal unloading rigs, alternating current motors are equipped to give dynamic braking in lowering. This is accomplished by applying direct current to the primary windings and adjusting the rotor resistance to control the braking effect. The necessary low direct voltage is obtained from a small motor generator set or by a generator connected to the hoist motor directly. This scheme is not practical for general use. There has been recently developed a so-called "solenoid load brake," having two solenoids. One of these is connected across primary voltage and is energized only while hoisting. At standstill or when lowering this solenoid is released, causing a small braking torque. The second solenoid is connected across the rotor of the motor. When this solenoid is de-energized, as at standstill, full braking torque is obtained. When this solenoid is energized; the braking torque is relieved in proportion. As this solenoid is connected across the rotor voltage, the higher the speed in lowering, the less the slip and the lower the rotor voltage, hence the greater the braking torque. The brake thus automatically adapts its effort toward controlling the speed. This type of brake will probably find more extensive use on ac equipped cranes in the future.

The holding brakes for any crane should, in general, be capable of exerting a torque equal to 125 per cent rated motor torque. The brake will then hold a somewhat higher load due to friction of the hoisting gear. Cranes not equipped with mechanical load brakes, in sizes of about 20 tons and above, are advisedly equipped with a second holding brake. The main holding brake is applied to the motor shaft, the second brake to the first reduction shaft. The brake on the motor shaft should be a shoe type or disc type brake, to avoid side thrust on the armature shaft. The second brake is usually a band brake arranged for maximum effort in the down direction.

The trolley traversing or "racking" drive of the overhead traveling or gantry crane ordinarily comprises one motor, driving through two or more gear reduction to the axle shaft of two of the four trolley wheels. On man trolleys of coal and ore bridges the trolley drive usually takes the form of two or more motors, each driving a pair of wheels through a single gear reduction. This gives good tractive effort by driving as many wheels as possible and is favorable to the uniform distribution of trolley weight.

The traversing speed of a trolley depends on the capacity, length of span and nature of service. On a large ladle crane the trolley speed, with load is usually

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about 75 feet per minute. General service cranes have traverse speeds ranging from 125 to 200 feet per minute, the higher speeds being for such as loading cranes, where speed is desirable. Man trolleys for coal and ore bridges usually range from 600 to 1000 feet per minute, sometimes higher. The figures given above refer to load conditions. Without load the speeds may be 50 to 100 per cent higher, depending on relative weight of trolley and load and motor characteristics.

The work required of the trolley traverse motor, or motors, comprises the following elements:

- To overcome journal and track friction.
- To overcome friction of drive mechanism.
- To accelerate trolley and load.
- To accelerate motor armature and revolving mechanism

The so-called "friction load" is made up of rolling friction, flange friction and journal friction at the axles and bearing and gear friction in the drive mechanism. Rolling friction depends upon the diameter of wheels, condition of track, whether all wheels are true circumference, etc. Flange friction depends on wheel alignment, track alignment and wheel end play. Because of these many variables the power for driving a trolley or bridge may vary over rather wide limits. The following formula is sometimes used to determine axle and rolling friction or so-called friction draw bar pull.

$$DB = K \frac{(.10r + .002) W}{R \times e}$$

Where DB = friction draw bar pull or combined traction of driving wheels—pounds.

r = radius of wheel axle—_inches.

W = total weight, trolley and load—pounds.

R = wheel radius—_inches.

e = efficiency of reduction shafting and gear-
ing, usually about 80 per cent for trolley
drive.

K = a multiplier— $1\frac{1}{4}$ to $1\frac{1}{2}$, to cover flange
friction or other uncertainties.

Inasmuch as trolley travel friction is susceptible to a number of somewhat indefinite variables, it is best, perhaps, to use values determined from practice. It is found that friction draw bar pull for a trolley is usually within the range of 15 to 30 pounds per ton of load, depending upon size of wheels and axles and drive arrangement. Rolling friction increases with the speed but, within the limits of speed of cranes or bridge trolleys, this variation is of less magnitude than other variables, so that a fixed value of friction draw bar may well be used.

Having determined the draw bar pull, the hp necessary to drive the trolley at free running speed may be found from the simple formula:

$$HP = \frac{D_r \times W \times V}{33000 \times 2000}$$

Where D_r = friction draw bar, pounds per ton.

W = weight of trolley and load—pounds.

V = free running speed—feet per minute.

The force or draw bar pull necessary to accelerate a crane trolley may be determined from the simple product of mass times acceleration. Thus

$$D_a = \frac{2000 \times a}{G}$$

Where D_a = draw bar for acceleration—pounds per ton
a = ratio of acceleration—feet per second per second.

$$G = 32.2$$

The rate of acceleration of crane trolleys varies within a range of $\frac{3}{4}$ to 3 feet per second per second. A rate of 2 feet per second per second is about as rapid as feasible without excessive swing of suspended load, or discomfort to the operator. This value should be used for fast cranes and man trolleys and where the trolley must spot over a swinging hook. A lower rate is advisable for heavy loads and trolleys with rigidly suspended loads. A low rate of acceleration may be used on standby cranes in order to reduce motor size. A trolley having but one-fourth of the wheels driven cannot be accelerated faster than 2 feet per second per second without wheel slippage.

Using the value of 2 feet per second in the above formula, the draw bar pull for acceleration becomes 125 pounds per ton. It may be seen that this draw bar pull for acceleration is several times the 15 to 30 pounds per ton of friction draw bar. It is thus evident that a motor producing the above acceleration must exert, during the starting period, much higher torque than during free running periods. Since free running load must be considerably less than rated load, acceleration will continue for sometime after all resistance is cut out and the motor is across the line.

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(To be continued)

250-TON SHIP CRANE FOR THE U. S. NAVY.

A contract has recently been awarded for the construction of a 25-ton revolving crane to be mounted on the hull of the U. S. battleship "Kearsarge." This is stated to be the largest seagoing crane under consideration, and it is the intention to transport the ship, with its crane, to whatever port requires its services. The "Kearsarge," launched in 1898, is 375 feet o.a. by 72 feet beam, with 23 feet 6 inch draught, on 11,520 tons displacement. The guns, turrets and armour will be removed and bulges added, giving a total beam on w.l. of 92 feet, for increased stability. The 250-ton crane falls consist of two 125-ton blocks on the jib, and an equalizer block at the hook. A 40-ton auxiliary block is also suspended from a traveling trolley on the jib.

The jib is luffed by the usual arrangement of vertical screws with nuts on the elbow of the jib. The range of these screws permits the jib to be luffed to all working positions, and also to be lowered into a position, approximately horizontal when the jib outer end rests in a lattice-work cradle at the after-end of the vessel, and is ready for sea. The whole of the working arrangements of the crane are described in detail, and the operating speeds for all the functions of the crane are given. Identical motors, eight in all, mill type, series wound, 110 hp, are used for the various operations.—The Technical Review.

OVEN ACCIDENTS FEWER.

According to the bureau of mines accidents at coke ovens in the United States in 1920 caused the death of 49 employes and the injury of 3,415 others, compared with 53 deaths and 4,031 injured in 1919. In 1920 the coke industry employed 28,139 persons, each employe averaging 319 working days in the year.

Casting Large Pipe Fittings

Eastern Shop Makes 96-Inch Elbows for 10,000 K. W. Installation for Steel Plant, In Dry Sand Mould — Interesting and Successful Methods Produced High Class Castings.

By JAMES J. ZIMMERMAN,
Assistant Superintendent, Scott Foundry, Reading Iron Co.

THE Scott Foundry, now the mechanical department of the Reading Iron Company in Reading, Pa., is one of the oldest foundry and machine companies in the east. Its history covers a period of progress dating from early in the eighteen hundreds. Its present product, in addition to the maintenance of the above company's mills and plants, covers the manufacture of all classes of heavy machinery, especially rolling and sugar mills and cotton baling presses. The foundry, for it is in this our readers will be most interested, is similar to any other of modern type. It differs very substantially, however, for in addition to operating two cupolas, it operates three air furnaces, in which rolls and special high grade castings, which require high strength and corresponding physical properties, are made. In addition

to making iron, steel castings are produced. The steel is made in a tropenas converter. Pipe balls are cast from special manganese steel made in a crucible furnace.

Recently this Company contracted for the furnishing of a number of large pipe fittings for the 96-inch exhaust line of a 10,000 kw installation, which consisted of a number of special fittings, reducers and elbows. It is the casting of the 96-inch elbows that the writer wishes to describe in this article.

The elbows, as shown in Fig. 1, were made from cast iron with walls $1\frac{1}{2}$ inches thick, and weighed 27,600 pounds each in the rough. The flanges were finished $2\frac{1}{4}$ inches in thickness by 108 inches in diameter. A 24-inch outlet can be seen and also four suspension lugs.

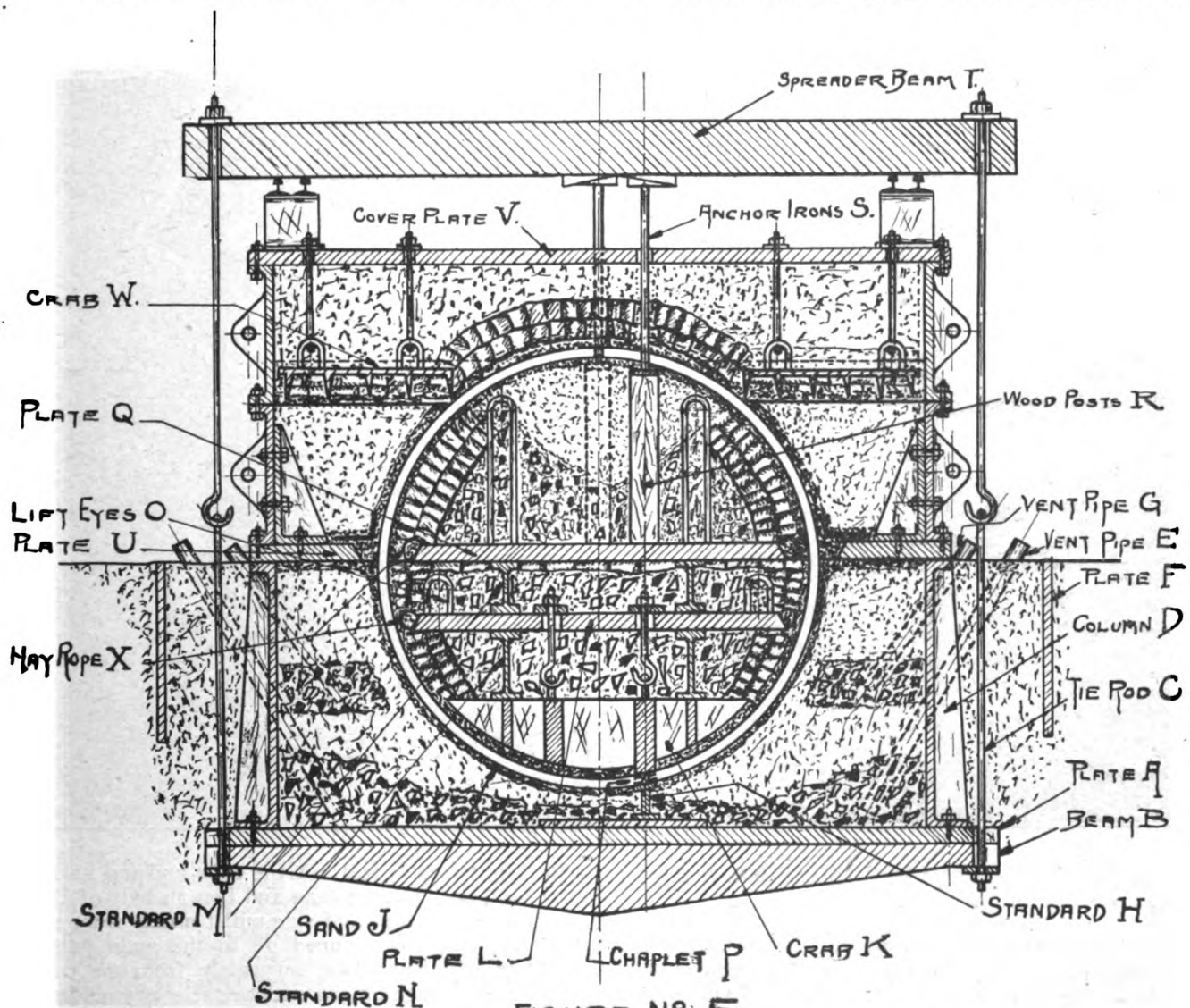
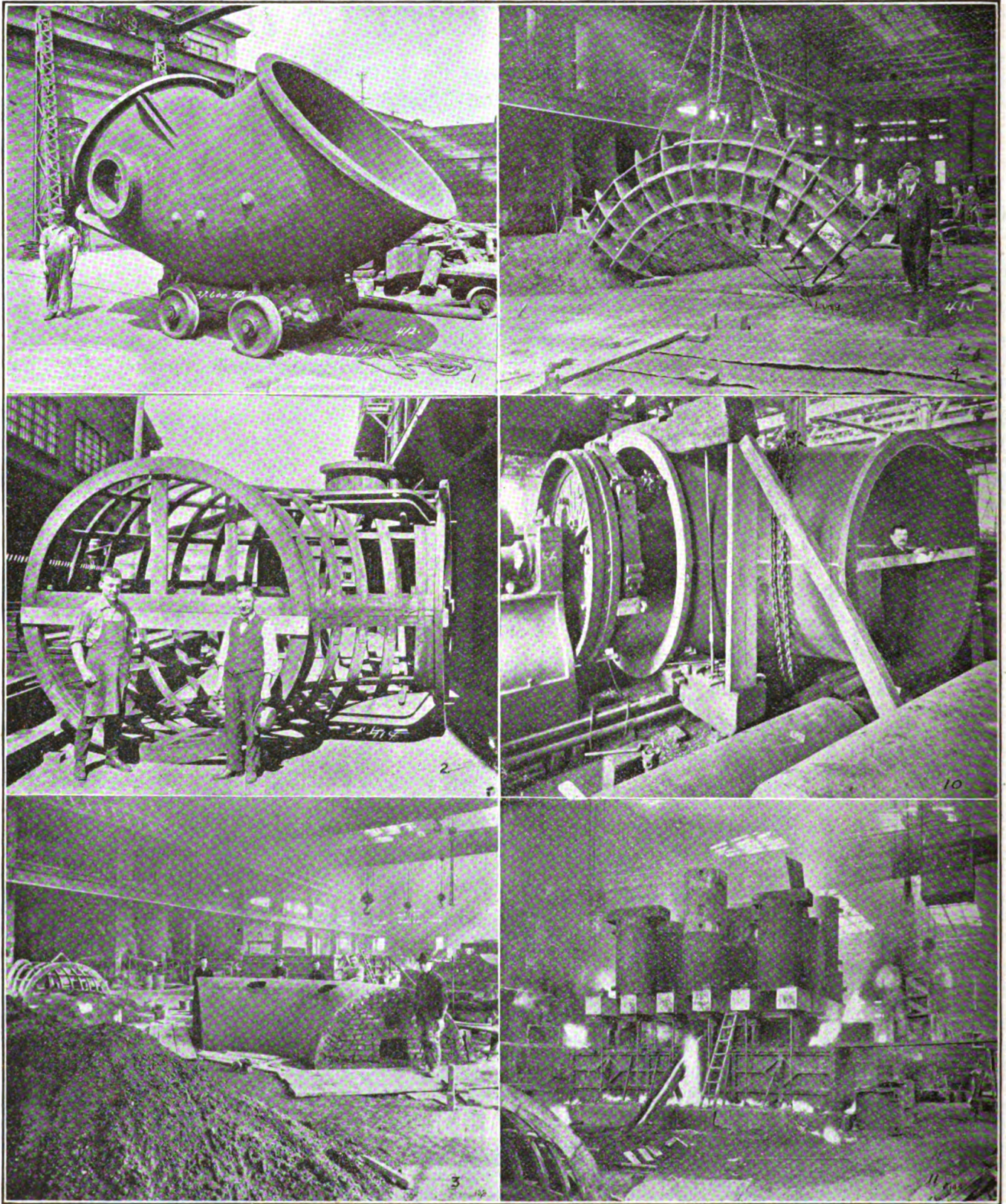


FIGURE NO. 5.
SHOWING METHOD OF THE CONSTRUCTION OF THE MOULD.



The radius on the neutral axis is $94\frac{1}{16}$ inches.

Patterns.

A skeleton pattern, as shown in Fig. 2, was used for making both the core and mould. It is not necessary to say anything especial about this pattern except that particular attention was paid to accuracy. It was split in halves, as shown in the background of Fig. 3, and

was used as such, half for the cope and top half of the core, and half for the drag and bottom half of the core. The suspension lugs and side outlet nozzle were separate patterns, and were pinned on to the main pattern, in order to withdraw them separately from the cope and drag. The flange on the outlet nozzle was made in sections, in order to permit its being picked from the drag. The slot in the suspension lugs was cored and necessarily

required a core box, as did the core for the nozzle.

The crab, as shown in Fig. 4, was made from a pattern, while all other fixtures, such as plates, flask sides, etc., were open sand castings, and consequently required no patterns.

Building up Mould.

In constructing the mould, the procedure was as follows:

- First—the drag
- Second—the bottom half of core
- Third—the top half of core
- Fourth—the bottom section of cope
- Fifth—the top section of cope.

This is illustrated best by sectional view Fig. 5. After the hole in the floor was dug to a depth of about 7 feet, the plate (A), in two sections, which covered the entire bottom of the mould, with six beams under it, through which the $1\frac{3}{4}$ -inch tie rods (C) ran, was leveled up. Next the standards or cope supporting columns (D), of which there were six on each side of the mould, were placed in position and the initial part of the drag was begun by spreading a bed of cinders over the entire bottom and placing the deep vent pipes (E). These deep vent pipes were four inches in diameter, and numbered three on each side and two on each end of the mould. Next a temporary shoring, approximating the outside diameter of the pattern, was placed in the drag, in the position which would later be occupied by the pattern, and the drag filled in with sand and cinder and rammed up. This included the placing of the 3-inch upper vent pipes (G), of which there were three on each side and two on the ends, as well as the reinforcing or shoring plates (F), also the setting of the chaplet supporting standards (H) of which there were three placed 10 inches away from the center line of the elbow, as shown in Fig. 6.

Next the temporary shoring was torn away, and a layer of facing sand, denoted by letter (J), was spread and upon it the bottom half of the skeleton pattern with nozzle and two suspension lugs on same was placed, rammed up and swept off. Upon this a layer of paper was placed, and work begun on the construction of the bottom half of the core. This part of the work was begun by placing the crab (K) so that the three lugs, noted on Fig. 4, came directly over the chaplet standard (H). The chaplets then came between two metal surfaces, and in this way helped support the heavy core and maintained an even space for metal which formed the elbow. Between the mould and the crab a layer of facing sand was spread, and upon it the entire bottom half of the core was constructed of brick, loam and cinder, as shown together with the cast iron plate (L), standards (M) and (N), hook bolts and lifting eyes (O). Note that so far as we have gone, all the weight of the core was supported on the metal plate (A) through the standard (H), chaplet (P), crab (K), standard (N) and plate (L), and that no weight was thrown on the sand mould except on the core prints, which are shown in Figs. 6 and 7, which were the same diameter as the core itself and extended beyond the faces of the flanges into the cope and drag on each end for a distance of 30 inches. Vent pipes not shown were run from each end of this lower section of the core to the floor line.

Next the top half of the core was built up by placing the cast iron plate (Q) with lifting eyes in same directly on the lower half of the core, and building up with brick, loam, cinder and facing sand. Note the hay rope

(X) at sides of plate (Q) and plate (L) in lower half, to permit contraction of the elbow after pouring without fracture or harm. When this top half approximated the required size, the top half of the skeleton pattern was placed over it and the core was swept off and finished to the outside diameter of the pattern. Note at this point the 6-inch square wooden anchor posts (R) with iron plates upon them with the anchor iron (S) in turn upon them. These anchors were run up to the spreader beams (T), of which there were six and through which the rods (C) passed on down to the bottom beams (B) thus tying the entire mould together. These anchors were forced down tight by means of wedges, thus preventing the core from swinging upwards and assisting the core prints in keeping the entire core down. In this way any movement of the core was prevented, and the required thickness of the walls of the elbow obtained without distortion. The object of the wooden posts was that they charred from the heat of the metal and crushed. Hence there was no chance of the elbow cracking on cooling, due to contraction or shrinkage. You will note that both halves of the core are held down solid, the bottom half by the top half, and the top half

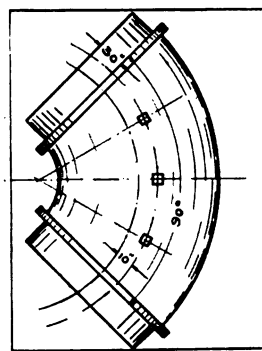


FIGURE NO. 6.
SHOWING LOCATION OF CHAPLETS.

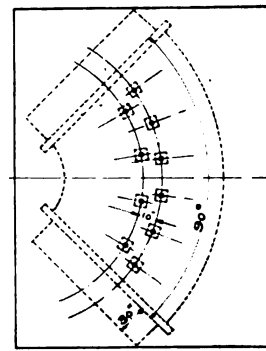


FIGURE NO. 7.
SHOWING LOCATION OF ANCHOR RODS

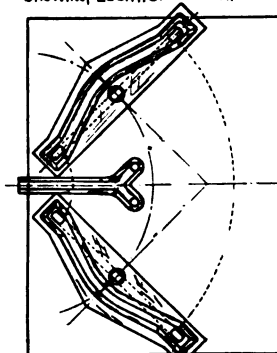


FIGURE NO. 8.
SHOWING GATES, RUNNERS, RISERS ETC.

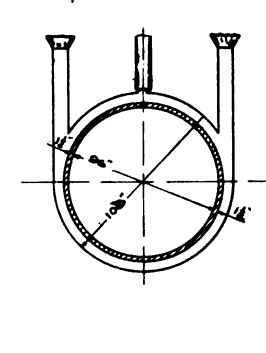


FIGURE NO. 9.
SHOWING LOCATION OF GATES AND RISERS

as follows, beginning with spreader beams (T) through the wedges, then the anchor irons (S) on through the plates and wooden posts (R) to the plate (Q), which rests on the bottom half of the core, with the core prints of course taking their portion of the work. These anchors were ten in number, four of which were on the center line of the elbow, and six on a line 10 inches off center, all as shown in Fig. 7. The finished core may be seen in Fig. 3.

A glance will show how the cope, which rested on a solid cast iron plate (U), and which was covered by a cover plate (V), which was in two sections, was constructed of sand, loam and brick but no cinder. The parting of the two sections of the cope was made on a line where the crabs (W) are shown suspended from the top cover plate. Next the mould was torn apart and

finished after the pattern, including lugs and outlet pieces, was removed. After finishing and slicking the faces, the cope and cores were taken to large core ovens for drying, while charcoal fires were built in the drag. You may therefore see that the elbows were dry sand castings.

After drying, the cores, including those for the outlet nozzle and suspension lugs, were set and the entire mould was assembled, and all rigging such as tie-rods, etc. tightened securely. The risers, runners, pouring basins, gates and pop gates or run-overs were then formed, as shown in Figs. 8 and 9. Next the entire mould was weighted down, as shown in Fig 11, with a number of heavy chills, etc., which approximated 140 tons, computed, of course, on the theory that a body immersed in a liquid is buoyed upwards by a force equal to the weight

of the liquid displaced.

Next came the pouring, as can be seen in Fig. 11, which was done simultaneously from both ends of the mould and through four gates (two on each flange), as shown in Fig 9. Immediately after pouring and settling, the weights were removed and as much of the mould as possible was torn down, and the sand portion in the top half of the core dug out, so as to relieve strains from contraction, which might have caused checking or cracking of the elbow. After four days the elbow was dug out, and cleaned and transferred to the machine shop for machining. Fig. 1 shows it on its way to the machine shop, and Fig. 10 shows one of its mates without nozzle or suspension lugs being machined in a nine foot engine lathe.

Flue Dust Production and Consumption

The Reduction In Amount of Flue Dust Produced and the Recovery and Use of All Dust Is a Main Factor In Economizing Cost of Producing Pig Iron.

By F. H. WILLCOX.

ON January 1, 1921, the rated capacity of the United States was 43,000,000 tons of pig iron per year. The highest ratio of output to rated capacity was reached in September, 1918, when 93.5 per cent of rated capacity was attained. Perhaps it may be assumed that 75 per cent of rated capacity may be realized in an average good year, with a normal stimulus of sales prices commensurate with costs of raw materials, freights, labor, materials and fixed charges. This is 32,000,000 tons of pig iron per year.

Practically 4,250 pounds of ore are now required per ton of pig iron, indicating a yearly requirement of 61,000,000 tons of ore. Of the 4,250 pounds of ore charged per ton of pig iron, less than 4,000 pounds is actually recovered as pig iron. There is an appreciable loss of metallic iron in the slag and a very considerable loss of iron in the flue dust.

Flue dust losses vary. As high as 600 pounds of flue dust per ton of pig iron is on record for a number of blast furnaces over the duration of their blast campaigns. As low as 60 pounds of flue dust has been established at certain operations producing as much tonnage as with the higher dust production rate.

From considerable data it is apparent that the average rate of flue dust production is as follows:

Pounds of flue dust per ton iron at dust catcher.....	150 pounds
Pounds of flue dust per ton iron at gas cleaning system.....	95 pounds
Pounds of flue dust per ton iron through gas cleaning system.....	5 pounds
Total pounds flue dust per ton iron.....	250 pounds
Equivalent iron ore lost.....	225 pounds
Iron ore charged.....	4,250 pounds
Loss.....	5.5 per cent
Tons flue dust per day—500 tons pig iron	
At dust catcher.....	33.5 tons
At gas cleaner.....	20 tons
At stoves and boilers.....	1.15 tons
Grains dust per cubic feet gas after dust catcher.....	10.8 grains

Grains dust per cubic foot gas at dust catcher.....	4.8 grains
Grains dust per cubic foot gas at gas cleaner.....	4.8 grains
Grains dust per cubic foot gas after gas cleaner.....	0.2 grains

If dry cleaners are used after the dust catcher practically all the 20 tons per day may be recovered if suitable tight conveying systems are used and the dust mixed with water in a pug mill to about 12 per cent moisture content before discharge into cars. The less effective cleaning usually attained in dry cleaning systems may slightly reduce the amount of dust recovered from 20 to 18.5 tons, and increase the amount going into the stoves and boilers from 1.15 tons to 2.85 tons per day. If wet washers are used about 95 per cent of the equivalent dry 20 tons of dust may be recovered by suitable settling basins, leaving 1.00 ton going to the sewer. These figures correspond to about 210 grains of solids in washer discharge water and 11 grains in settling basin discharge water.

To summarize average practice today, it may, therefore, be said that of a total of 54.65 tons of flue dust produced per 24 hours, 52.5 tons may be recovered, leaving about 2¼ tons going in part to the stoves and boilers, and in part to sewers, the proportion of the dust in either case depending upon the type of gas cleaning plant used.

It is indicated, therefore, that for a pig iron production of 33,000,000 tons per year, something like 3,500,000 tons of flue dust is actually produced, probably equivalent to 3,100,000 tons of ore per year, or 1,635,000 tons of pig iron per year, or the product of nine 500-ton blast furnaces for one year.

Of the above flue dust production it appears from the basis of data from a considerable number of operations applied to the total, that approximately 80 per cent of the total dust catcher dust is re-used, either raw, sintered, nodulized or briquetted. This amounts to less than half of the total, or 1,700,000

tons of dust catcher dust re-used per year; 1,800,000 tons are not accounted for.

This 1,800,000 tons is very largely shot into the air and distributed over the country or city at plants not having gas cleaning plants. Surprisingly little stays in the stoves or boilers out of the tremendous amounts passed through in 90 or 120 days. For this very reason the amounts of flue dust made are not commonly supposed to be as great as mentioned. At furnace plants having gas cleaning plants, wet or dry, by far the greater amounts of dust either carried in washer water or recovered dry are allowed to escape into streams or sent out for fill. Usually over 95 per cent of these dusts will pass through a 100 mesh sieve. It is not commonly realized what really high quantities are allowed to escape. It is the writer's estimate that of the 1,800,000 tons mentioned in this paragraph, quite probably 1,500,000 tons are never recovered.

This 1,500,000 tons yearly loss of flue dust would be equivalent to about 1,350,000 tons of ore, or about 700,000 tons of pig iron, the yearly production of four 500-ton blast furnaces. The loss of labor, coal, boat trips and pig iron production is, in the aggregate, a very considerable item. In fact it is a very considerable item even for a single 500-ton blast furnace, and for the so-called average 500-ton stack it totals up to 11 tons of pig iron lost per day—with whatever that means in cost of equivalent tonnage of ores delivered to the furnace top and lost profits in the pig iron tonnage in question. A fair guess would be:

Cost of 21 tons ore at \$6.55.....	\$136.00
Profit on 11 tons pig iron at \$3.00.....	33.00
	\$169.00
Loss per ton pig iron.....	\$ 0.34

The question of ores lost as flue dust in consequence of slips is, in the writer's opinion, a minor item. Tight top furnaces and gas cleaning systems recover virtually all such dusts, or at least make possible the recovery. Moreover, the relation of magnetic and non-magnetic proportions of flue dust indicates that by far the greatest proportion of dust arises from the normal movements of the gases and burden, and not from slips.

The reduction of these losses is a practical problem and not one fraught with any particular difficulties. Considering that the ores, or flue dusts, carried out of the dust catcher are fine and as a matter of fact exactly as rich in iron as the burden, that a gas cleaning system aside from its other advantages makes recovery possible, that up on the range millions of dollars are being expended to mine, beneficiate and prepare leaner ores than our flue dusts, it would appear quite practicable to recover and use all of the dusts made, barring possibly 2.5 tons which are inevitably lost in the system.

One logical step is the further development of furnace lines, coking practice, limestone preparation and adjustment of practice to reduce to a minimum the production of flue dust from the ores which must be used. It appears perfectly practicable and to be expected that with time for the changes involved, the average plant can reduce flue dust production to less than 125 pounds per ton of iron. This in fact is being accomplished at three plants at least, and probably more. This corresponds to a total production of about 33 tons of flue dust per day per 500-ton fur-

nace, dust catcher, gas cleaner and unremoved from gas.

The other step is recovery and use of dust made. No mention is necessary of the practicability of recovery and preparation of dust catcher dust as it is an accomplished fact. As for gas cleaner dusts, about 20,000,000 tons furnace capacity is equipped with secondary cleaners, wet or dry type. This is nearly half the total capacity and probably is more than half of the usual capacity that actually operates on more or less full time. It is believed that 1,000,000 tons of flue dust are lost at these plants every year. These dusts can be recovered for a capital expenditure, per 500-ton plant, of certainly less than five cents per ton pig iron for plant, and less than fourteen cents per ton pig iron for plant operation. This would net fifteen cents per ton pig iron, or about \$27,500 per year for a 500-ton furnace, over and above extinguishment charges on equipment cost and labor and material in operation of recovery and preparation plant.

Although a minor point, it may be pointed out that complete recovery of flue dust is worked out to afford a practically dustless plant. This would perhaps have been beside the point not so long ago, but at least three plants today have taken steps—all with a different plan—to obtain positive relief from the nuisance of clouds of flue dust.

In view of the increasing expenditures resorted to for securing ores, and the evident necessity of economies in pig iron production, however obtained, both the reduction in amount of flue dust produced and the recovery and use of all dust unutilized is bound to be of increasing importance.

NEW METHOD OF MANUFACTURING CAST IRON AND STEEL IN FRANCE.

It is reported that the Basset Steel Works (Aciéries Basset) have recently discovered a new method of manufacturing cast iron and steel. Mr. Lucien Basset states that, after having obtained satisfactory results in a furnace of 25 tons capacity, he has this month made conclusive experiments in a 100-ton furnace resulting in the manufacture of steel at a cost of 110 francs a ton. This is less than the average pre-war cost. Mr. Basset has also stated that his company will begin in the course of a few weeks the construction of 12 furnaces having a total daily capacity of 3,000 tons of steel. He estimates the total cost at 30,000,000 francs.

According to this method the coal which is consumed in the furnace enters into the manufacture of metallurgical products simply as an element producing heat and not as an element which throws out gases acting on the raw material. It appears that the application of these principles results not only in an important economy of fuel, but also eliminates the necessity of utilizing coke. Consequently the discovery of this process is of considerable importance to France.

PLAN TO BUILD MILL.

Proposed construction of a factory and rolling mill at an estimated cost of \$600,000, at Louisville, Ky., by the Collapsible Rim Manufacturing Company, Ashville, N. C., is reported. According to the report the Collapsible Rim Manufacturing Company has purchased the conveyor machinery plant of the Buzz Engineering Co., which will be utilized for some time, but which will be supplanted by new structures later.

Discussion on Open Hearth Practice

Some Facts To Be Considered In Relation to Open Hearth Furnace Temperature to Furnace Output.

By HENRY WILLIAM SELDON, B.S., Met.Eng.,
See-Seldon & Associates.

OBSERVATION and experience with open hearth furnaces using producer gas in the past has shown the furnace output per hour to follow a general curve such as shown in Fig. 1.

Practice has shown that the life of a furnace is dependent upon many factors, namely, construction, drying out, heating up, regulation, operation and attention.

If we assume a new furnace as constructed to a proven design, built to exact dimensions at all points and the workmanship first class, we will have provided only the rough tools and the resulting life of the furnace, total tonnage and tons hour output will still be unknown factors.

There has been considerable discussion as to the length of time which should be spent upon the operations of drying out and heating up, but to our mind it is much better practice to err upon the side of taking plenty of time for these operations.

It should be remembered that not only must the body of the furnace be considered but likewise the downtakes, slag pockets, checkers, flues and stack must also be dried out and heated up gradually.

Moisture is present not only on the exposed surfaces of the bricks, but likewise completely through the exposed brick as well as the bonding material and brick making up the unexposed parts of the furnace. Many of these walls are 18 inches and more in thickness.

After the moisture has been removed from the furnace the heating up process is gradually increased. This should be increased very slowly at first in order to allow the center of the exposed brick to become heated and prevent not only spalling off on the surface, but also to prevent hidden cracks forming by too rapid expansion. Until the exposed brick have assumed a red heat all flame should be prevented from touching the brickwork.

The practice of making bottom on a new furnace before charging is a very good one and the additional seasoning of the roof and the heating up of the downtakes, checkers, etc., is very beneficial and very often prevents the gas from traveling to the roof after the furnace has been charged.

It is a well-known claim among furnace men that the better seasoned a furnace is the faster it will make steel later on without damage to the brickwork. The continual heating of the roof brick has the effect of rendering it better able to withstand high temperatures without burning.

This is the second installment of a series of articles to be written by Mr. Seldon on Practical Open Hearth Furnace Practice. Mr. Seldon, before joining Theodore S. See in forming the See-Seldon and Associates Engineering firm, spent ten years in open hearth work with the Cambria Steel Company and the Jones and Laughlin Steel Company. The many experiments made during his operating career make him particularly suited to write on this interesting subject.

To our mind the reason for the roof brick being better able to withstand high temperatures after, say 50 heats have been taken out, is due to the physical condition of the roof at that time. During the early life of a furnace the roof is more or less irregular and the bricks are porous. Later on the roof is worn smooth and the bricks become glazed, and if the furnace is working and handled properly the roof becomes a smooth arch reflector against which the heat rays have less penetrating effect and we get the equivalent of a roof with a higher fusing point. This becomes so pronounced in an occasional furnace that you hear the first helper say you can't burn the roof. Such a statement as this is of course not meant literally, but only in a comparative sense.

This condition of roof should be the aim to procure on every furnace, but it is only obtained after careful and painstaking work on the part of all concerned.

When we have a furnace in this stage we are in a position to expect and obtain an increase in the tons per hour output without damage other than the unavoidable wear and deterioration which always goes on.

A furnace working properly heats up the charge and not the roof and side walls. An exception to this is true for all furnaces while charging and while the scrap is high on the ends on account of the gas being deflected. This condition very often necessitates either quicker reversing or a slacking up of the gas until the danger is eliminated, otherwise the gas will strike the brickwork and cause untold damage in a very short interval.

It is the quantity of heat or temperature developed by the flame over the bath and the extent to which this flame, visible or invisible, covers the bath that determines the tons per hour output of the furnace.

The higher the temperature developed the more rapidly will the scrap melt and the faster will the charge approach the temperature of the flame.

As the heat progresses and the lime begins to come up conditions change and we have stages during which the bath instead of absorbing the heat reflects it and it becomes imperative to slow up the gas to prevent burning the furnace.

What is required is an adjustable flame and means to increase the intensity and quantity at such times as the bath will absorb the heat. To be able to increase

the intensity of the flame without damage to the walls and roof of the furnace is what is required.

Furnace temperature is not always an indication of a rapidly working furnace, in fact the converse is often true. Usually in the best working furnace the brickwork is comparatively cool, while in an old furnace which is not working the bricks are white hot continually. The heat must be supplied to the bath and not the walls and roof, this means the flame must keep to the bath.

In the majority of furnaces there is a cycle of conditions or speed of working. During the first stage of the run it has often been impossible to get the furnace to work sharply in spite of all attempts at regulation. Later for no apparent reason the furnace starts working sharply and continues to work with this quality for several weeks. In time the furnace begins to slow up and in spite of all attempts at regulation or forcing of the furnace the time of heats continues to increase. This condition gradually gets

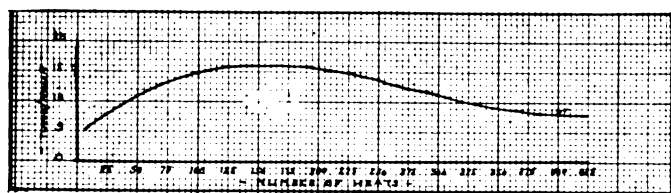


Fig. 1.

worse and usually because of continued forcing the roof and walls are burned away and the furnace is taken off.

The point aimed at in the preceding paragraph is to try to show that there is "a something" about the operation or construction of an open hearth furnace which has not been fully understood. Some furnaces go through an entire run without ever attaining this desired condition.

By a furnace working sharply is usually meant one which cuts down the scrap quickly, can produce results with less gas, flame lays down over the bath, roof and walls cooler than flame, lime comes up quickly and at all points, good reactions from additions of hot metal, carbon burns out of bath quickly and bath heats up to tapping temperature quickly.

It has been suggested that "this something" which makes an open hearth furnace work sharply is "blow pipe action" and it sounds logical.

Blow pipe action is influenced by the individual pressures, velocities, proportions and relative directions of the incoming gas and air, and the temperature developed is influenced by the degree of pre-heating and the type of fuel.

An open hearth heat may be divided into four general stages as follows:

1. Time of charging
2. Time melting down
3. Time of reaction
 - a. De-phosphorizing
 - b. Refining.
4. Time bringing heat up to casting temperature.

It would appear the benefit derived from an increased flame temperature would be noticeable during stages 1, 2 and 4.

Stage 3 appears doubtful on account of the process of de-phosphorization taking place at a lower temperature and being incomplete when the bath is exces-

sively hot, as results with duplex have shown.

The process of refining among other reactions consists of removing iron oxide (Fe_2O_3) from the bath by carbon (Fe_2O_3 plus 4C equals 4CO plus Fe_3).

During the periods which this gas is being given off by the bath the incoming fuel gas is deflected to the roof and must be slacked down.

In stage No. 1 the limiting factors are the deflecting of the incoming flame by the scrap in such a manner as to injure the brickwork. Likewise the presence of flame in the furnace being a hindrance to the charging machine operator by increasing his chances for damaging the furnace roof by pushing a hole in it with scrap, also in his efficiently charging the furnace.

In stage No. 2 we see only beneficial results from higher flame temperature.

In stage No. 4 it should be possible with a flame temperature equal to that of natural gas to reduce the time at least one hour and in most cases eliminate it entirely so that by the time the bath is refined the heat will be hot enough to pour.

There is a temperature limit for the bath of an open hearth furnace above which it would not be advisable to go, namely, the fusing point of the banks. The danger line appears to be but a few degrees above the present casting temperature especially when a heat is held in the furnace for a short time after it is ready.

Other features to be considered before increasing the bath temperature are the pollution of the bath with iron oxide and the formation of a thin slag. These are important from the standpoint of quality of the steel and also the chemical action of a thin slag upon the open hearth banks.

FOUNDRY EXHIBITION IN 1922.

The uncertainties which for some time have surrounded the 1921 exhibition of the American Foundrymen's Association have been cleared up in a statement just issued by C. E. Hoyt, secretary of the association, from its offices at 140 South Dearborn Street, Chicago. Both the time and place of the exhibition of this year have been under consideration and there has also been discussed the question of postponement. At a meeting of the executive committee of the association held in New York, May 28, it was decided to hold the next convention and exhibit in April or May at a place to be selected by the Committee on Convention and Exhibits. Part of the statement of Secretary Hoyt is as follows:

"From the date of organization to 1911 the conventions of the American Foundrymen's Association were held in May or June of each year. In 1912 it was found necessary to postpone the convention scheduled for June at Buffalo until late in September, due to delay in completing the building in which the exhibits were to be placed, and since that time the annual meetings have been held in the fall.

"At the annual meeting of the board of directors of the association, in Rochester, N. Y., December 7, 1920, invitations for the next convention were referred to the committee on convention and exhibits. When this committee met in Cleveland on March 30 to consider the place of the next meeting it was found that in none of the eight cities considered was it possible to find, during September or October, adequate hotel accommodations and exhibition facilities to properly care for such meetings as were held in 1919 and 1920.

Electric Furnaces for Making Steel

General Features and Advantages of the Keller Furnace and of the Stobie Furnace — Classification of Electric Steel-Making Furnaces.

By ALFRED STANSFIELD, D.Sc., A.R.S.M., F.R.S.C.,
Birks Professor of Metallurgy at McGill University.

PART V.

CHARLES ALBERT KELLER, Managing Director of the "Société des Etablissements Keller Leleux," Livet Works, Isère, France, developed a furnace* of the series-arc type that resembles the Heroult furnace except in regard to the method of supporting the electrodes. The main peculiarity of his furnace consists in the fact that the electrode supports are not attached to the furnace, and that in consequence the electrodes must be lifted out of the furnace before the latter can be tilted to pour the charge. The independent support of the electrodes offers certain advantages, but interferes seriously with the easy tilting of the furnace and also means that the electrodes will be exposed to the air, while red hot, and that the holes in the roof through which the electrodes enter will be open while pouring the charge, and will allow the entrance of air and the exit of heat and gases from the furnace. In the early days of electric furnaces, when electrodes had to be changed as soon as they became too short for use, this method had some advantages; but the use, as at present, of threaded electrodes that can be lengthened so as to avoid the waste of stub-ends, seems to leave less advantage for this special form of construction. It may be added that the same method of electrode support was adopted by Nathusius in his first furnace which was employed in Friedenshutte, Germany, about the year 1912.

The Keller furnace shown in Fig. 24, was cir-

* C. A. Keller, "A Contribution to the Study of Electric Furnaces as applied to the Manufacture of Iron and Steel," Trans. Am. Electrochem. Soc., XV, 1909, page 110.

cular in plan and had four electrodes which were supplied with single-phase current. In a modern installation it is probable that two-phase current would be used with four electrodes, or three-phase current with three or six electrodes. The furnace is supported on a train of rollers and can be tilted, like the Campbell open-hearth furnace, by means of a hydraulic ram. The electrode holders are not attached to the furnace, but are suspended from independent supports, and the furnace cannot be tilted until the electrodes have been withdrawn. The system for supporting the electrodes is shown in the figure.

Each electrode hangs from the end of a hinged arm, A, and two of these arms are supported on each of the four pillars, PP. There are thus eight electrodes, of which four are in use at once and the other four are ready to replace these when they become too short for further use. To replace an electrode it is lifted up to clear the furnace, swung out of the way and a fresh electrode swung over the furnace and lowered into position. Electrical connection with the electrode holder is made by the flexible metallic conductors, CC, which fold up when the electrode is raised; a vertical rod, serving to keep them in place. Electrical connection to these conductors is made by a fixed system of bus-bars, B, with which each electrode arm engages when it is swung into position. The electrodes are, therefore, automatically disconnected from the electrical supply when removed from the furnace for changing. The four-electrode furnace shown, having two pairs of series-arcs, has nearly perfect

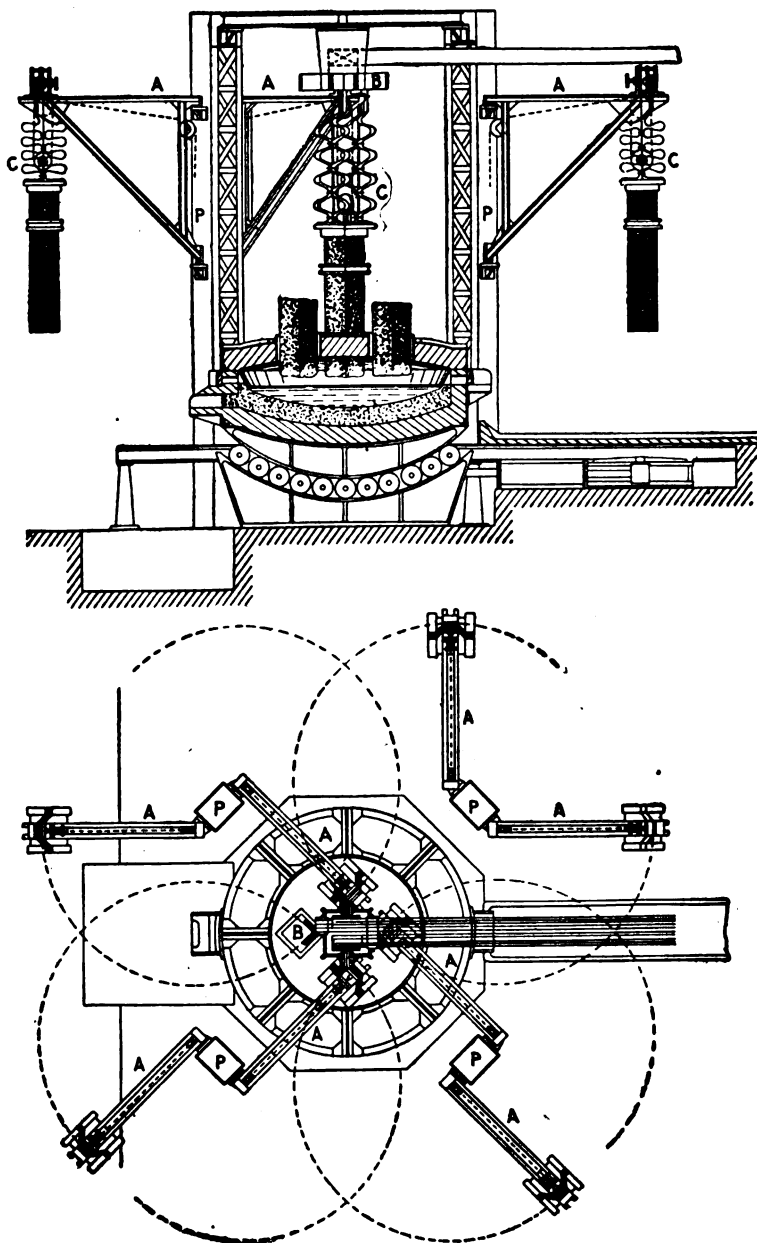


Fig. 24—Keller Steel Furnace.

symmetry of heating. It has also the advantage that the electrical supply bus-bars, being all brought to the same point, can be thoroughly interlaced and thus the inductance of the system can be kept low and the power-factor can be as high as 0.97 with 12,000 amperes.

The furnace was used to finish steel that had been made in the open-hearth furnace. A charge of 7.5

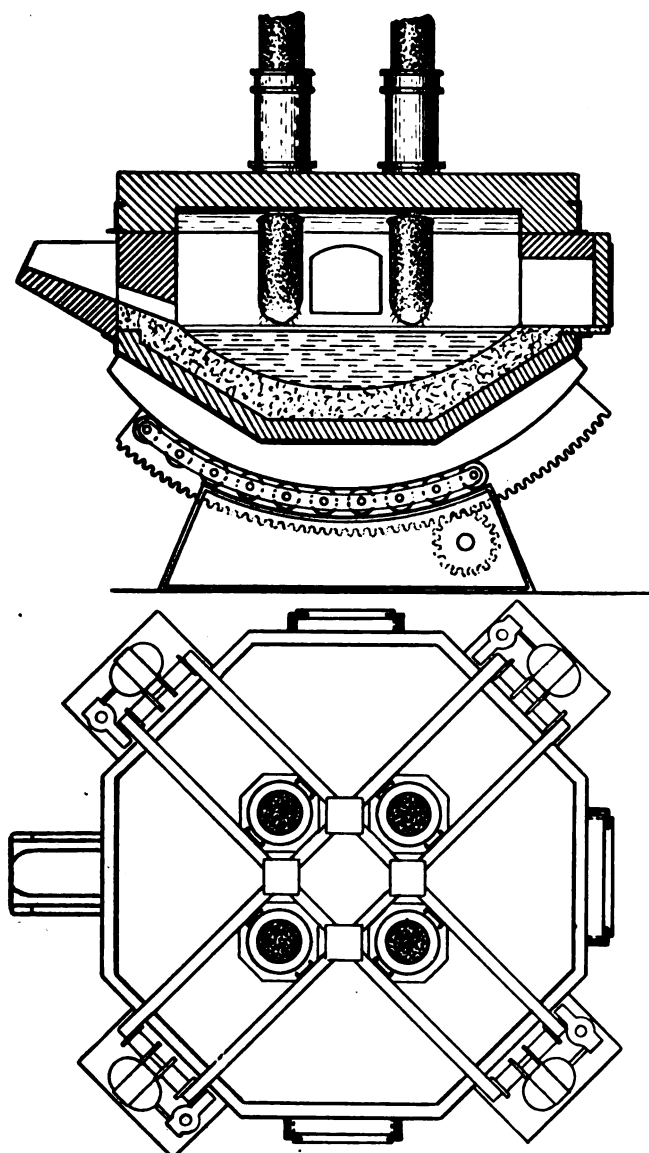


Fig. 25—15-ton Stobie furnace.

tons of steel containing 0.15 per cent carbon, 0.06 per cent sulphur, and 0.007 per cent phosphorus, required two hours and 45 minutes in the furnace with an average power of 750 kw; yielding a steel having 0.443 per cent carbon, 0.009 per cent sulphur, and 0.008 per cent phosphorus. The energy consumed per ton was 275 kwh. The electrode loss was about 26 pounds, costing 80 cents per ton of steel. This figure apparently does not include the cost of the waste ends and should probably be somewhat higher.

Stobie Furnace.*

This is a recent form of series-arc furnace which was employed in the North of England during the war.

*"Stobie 15-ton Electric Furnace," *Iron & Coal Trades Review*, April, 1918, p. 402.

It has been made in sizes up to fifteen tons and the electrical design has varied considerably in the earlier types. The newer furnaces, which have four electrodes and use two-phase current, will be described here.

The 15-ton furnace shown diagrammatically in Fig. 25, is octagonal in plan and has four electrodes arranged in a square. It rests on a train of rollers and is tilted by a 15 hp motor. The furnace can be tilted towards the working platform for pouring off the slag, and away from it for pouring the steel. The electrodes are supported and guided by means of a braced steel cross, which is shown in the plant but not in the elevation, and are lifted and lowered by motors which rest on the four corners of the furnace shell. The roof is arched in one direction only. The electrodes are supplied with two-phase current; though in an earlier form, star-connected three-phase current was used, and the fourth electrode was connected to the neutral point, thus carrying any unbalanced current. "Electrode Economizers" are used, which consist of light sheet-steel cylinders somewhat larger than the electrodes, which they enclose, and about two feet long. The lower end of each is sealed to the arch with fire-clay and its upper end is covered with a plate which fits the electrodes. This arrangement prevents the wasting away of the red-hot electrodes by oxidization in the air.

A 15-ton furnace at the works of the Stobie Steel Company at Dunstan-on-Tyne was making nichrome-steel heats in six hours from tap to tap, making twenty-four heats each week. The power consumption was 600 to 625 kw hours per ton of saleable ingots, with a melting loss of $2\frac{1}{2}$ per cent of the charged metal. The output of the furnace was 1,000 tons per month. The roof was replaced every third week, but was not worn out in that time. The power supply is not stated, but from the above data it would appear to be about 1,500 kw, which is rather small for that size of furnace.

The furnace at Dunstan-on-Tyne used the star-connected three-phase system of electrical supply with a connection from the neutral to the fourth electrode. This system appears to be satisfactory except that the fourth electrode will receive a variable amount of power which will in general be less than that supplied to the other electrodes. In the newer, two-phase system, each pair of diagonally opposite electrodes is connected in one of the electric circuits of the two-phase supply. This arrangement is more symmetrical than the other, but it has this drawback, in common with a single-phase furnace, that if one arc breaks, the arc in series with it will also break and both electrodes must be lowered before either arc can be restarted. The regulation of the electrodes, also, cannot be controlled by the current flowing to each electrode, as in a three-phase system, but will have to be operated by the voltage between each electrode and the body of the furnace.

THE ELECTRIC BLAST FURNACE.

In "La Technique Moderne" an article recently appeared reviewing the introduction, actual state of development, and the future of electric blast furnaces. The process of the reduction of iron ores is treated analytically, calculations for determining the quantity of carbon necessary for the reduction of impurities being included. A heat balance-sheet is also given.

Molybdenum and Molybdenum Steel

Occurrences of Molybdenum — Manufacture — Properties and Uses — Molybdenum In Steel, Over One Per Cent, Less Than One Per cent — The Manufacture of the Steel Itself.

By ARTHUR H. HUNTER,*
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PART II.

The Manufacture of the Steel Itself.

THE production of some 50,000 tons of molybdenum steel has served to place melting practice on a firm basis. Molybdenum may be added to the electric or open-hearth bath either in the form of calcium molybdate or ferro-molybdenum. Greater precautions are necessary in the open-hearth with the former than with the latter. In this type of furnace the method which has been found most advantageous is to make the addition as the charge is melting down and before the slag has formed. This practice insures a complete and uniform diffusion of the molybdenum through the steel. In this process nearly all of the molybdenum remains in the steel and losses, whether mechanical or due to volatilization and oxidation, are extremely small. The molybdenum in scrap can be recovered when remelted in like proportion to the original addition. The total alloy efficiency in average practice is well over 90 per cent. In the electric furnace the positive control of slagging and atmospheric conditions renders an even higher recovery possible.

The statement appears in a recent paper by Charles McKnight, Jr.†

"There are no especial precautions that should be taken in either pouring or rolling, except those which would be taken with any alloy steel, and it will usually be found that the percentage of product will be greater and the rejections for seams, segregations or piping less with molybdenum steel than with corresponding grades of alloy steels. This is particularly noticeable when a chrome-molybdenum steel is compared with a nickel-chrome."

Observations of a like nature are made by Martin H. Schmid°

"The blooming and finish rolling operations on molybdenum steel requires no special precautions other than those necessary on corresponding types of other alloy steels, and the practice, measured in per cent. of available finished product, is higher than in most types of similar properties. The tendency toward a minimum amount of inherent defects, both surface and sub-surface, is very pronounced, especially as compared with nickel and chrome-nickel steels.

amount of scalage, there is a marked advantage in the texture of the scale over that on nickel steels. The scale is a loose, non-tenacious one, freely flaking from the steel, showing no tendency to roll into surface and result in pitting."

Our own experience confirms the actual performance of molybdenum steel in mill operations and the manifest ability of molybdenum steel to process with pronounced ease and satisfaction.

The Physical Properties of the Finished Steel.

Molybdenum steels, as a class, when compared with other alloy steels which are in the same category from a commercial standpoint, treated to the same tensile strength, show:

- 1. A slightly higher elastic limit, hence a somewhat higher elastic ratio.
- 2. A higher elongation, hence greater ductility.
- 3. A much higher reduction of area, hence appreciably greater toughness.

This latter property is probably the most pronounced individual physical result of the addition of molybdenum to steel. From a great deal of data covering these three points, the writer has chosen the following tests, made under the supervision of Dr. J. S. Unger of the Carnegie Steel Company, as exemplifying them in the simplest manner.

Five steels, embracing only the accepted commercial tonnage types, analyzing as shown in Table A, were all heat treated to give the same tensile strength, i. e., approximately 125,000 pounds per square inch. The results were as shown in Table B.

Table A—Analyses.

Type of Steel	C	Mn	Ni	Cr	Mo
1. Carbon	.62	.45	...	...	...
2. Chrome	.49	.53	...	.60	...
3. Nickel	.40	.65	3.61	...	...
4. Chrome-nickel	.43	.57	1.60	.46	...
5. Chrome-molybdenum ..	.32	.72	...	.80	.27

Compared with the carbon steel, the chrome-mo-

Table B—Physical Properties.

Type	Tensile Strength Pounds Per Square Inch	Elastic Limit, Pounds Per Square Inch	Elastic Ratio	Per Cent Elongation in 2 Inches	Reduction of Area, Per Cent.	Izod Foot Pounds
1. Carbon	126,175	84,380	66.9	18.0	43.6	5.0
2. Chrome	125,300	107,225	85.6	18.0	56.5	66.5
3. Nickel	127,975	112,525	87.9	18.8	51.4	54.5
4. Chrome-nickel	127,975	111,025	86.8	19.8	60.3	54.0
5. Chrome-molybdenum	125,650	112,250	89.3	21.0	68.0	90.0

"Wide temperature ranges are available for rolling and forging, and, while there is no appreciable difference in the

†"Molybdenum Steels." Trans. Amer. Soc. Steel Treaters, March, 1921).

°"Molybdenum Steel and Its Application." Amer. Soc. Steel Treaters (presented April, 1921).

*Paper presented at the American Iron and Steel Institute, May 27, 1921.

lybdenum showed 33 per cent increase in elastic ratio, 16 2/3 per cent increase in elongation and 56 per cent increase in reduction of area. Compared with the nearest alloy steel, the chrome-molybdenum showed 1.7 per cent increase in elastic ratio, a little over 6 per cent increase in elongation and 12.8 per cent increase in reduction of area. The tensile strength of

all these steels having purposely been made the same, the only possible variables were these three.

The physical merit of a steel depending upon the relation of all its properties, it is the cumulative effect the increase of each that gives to the molybdenum steels their superior merit. In this connection reference is made to the paper by J. D. Cutter* proposing the use of a merit index, developed by H. T. Chandler, for the comparison of different steels by employing a formula embracing the four static properties and indicating roughly the work done in breaking a test piece.

In direct relation to the foregoing, it should be noted that tests by the Izod machine on these steels showed chrome-molybdenum to possess a resistance to impact of 18 times that of the carbon steel and 34 per cent greater than the nearest alloy steel. As the impact test merely measures the work of rupture under a suddenly applied load, these results, which have been amply corroborated, clearly show the cumulative effect of the higher elastic ratio, elongation and reduction of area for a given tensile strength possessed by the molybdenum steels. Bending tests further bear this out.

In order to give an idea of how the chrome-molybdenum series of alloy steels compares with chrome-vanadium steels, a comparison of two types of each follows. The data on both of the chrome-vanadium steels is taken from a recent booklet published by the Vanadium Corporation of America presenting charts plotted by the Metallurgical Department of the United Alloy Steel Corporation. The data on both of the chrome-molybdenum steels was furnished the writer by the Metallurgical Department of the same company. Both series of tests were made on open-hearth steels.

Type 1—.40 to .50 Carbon.

Type	C	Mn	Cr	V	Mo
Chrome-vanadium	.47	.85	1.19	.15	...
Chrome-molybdenum	.41	.68	.95	...	.24

Sections, $\frac{7}{8}$ inch round, quenched in oil from 1560 degrees F. (V.) and 1500 degrees F. (Mo.). Drawn to show tensile strengths indicated.

—250,000 lbs. T. S.—			
	E. L.	El. %	R/A.
Cr-V.	215,400	11.0	38.5
Cr-Mo.	222,000	9.0	43.5

—225,000 lbs. T. S.—			
	E. L.	El. %	R/A.
Cr-V.	201,000	12.3	42.3
Cr-Mo.	201,000	10.3	47.9

—200,000 lbs. T. S.—			
	E. L.	El. %	R/A.
Cr-V.	184,000	14.0	47.0
Cr-Mo.	179,000	13.3	52.2

Type 2—.23 to .30 Carbon.

Type	C	Mn	Cr	V	Mo
Chrome-vanadium	.27	.71	.98	.15	...
Chrome-molybdenum	.28	.64	.70	...	.20

Sections, $\frac{7}{8}$ inch round, quenched in water from 1625 degrees F. (V.) and 1525 degrees F. (Mo.). Drawn to show tensile strengths indicated.

—175,000 lbs. T. S.—			
	E. L.	El. %	R/A.
Cr-V.	157,300	15.0	60.5
Cr-Mo.	163,400	15.5	59.3

*Suggested Method for Determining Comparative Efficiency of Certain Combinations of Alloys in Steel. Trans. Amer. Soc. Steel Treathers (1920), 1,188.

—150,000 lbs. T. S.—			
	E. L.	El. %	R/A.
Cr-V.	137,500	17.7	62.8
Cr-Mo.	141,200	18.7	63.4

—125,000 lbs. T. S.—			
	E. L.	El. %	R/A.
Cr-V.	112,400	21.2	66.9
Cr-Mo.	117,800	22.8	69.0

It should be noted that the molybdenum content of both of these types of the chrome-molybdenum steel is extremely low. For a comparison on a purely commercial basis, steels containing double the above content of molybdenum and showing higher physical properties might well have been used. Considering the lower manganese, chromium and molybdenum contents of the last mentioned molybdenum steel, a comparison between its properties and those given in the table of Dr. Unger is interesting.

It has been stated above that the physical properties of molybdenum steel were progressively better as the molybdenum content is increased up to 1 per cent, and the table of properties below is presented to illustrate this point:

Sections, $1\frac{1}{4}$ inch round and $1\frac{1}{4}$ inch square, quenched in water from 1550 degrees F. to 1600 degrees F. Drawn to show a tensile strength of 175,000 lbs. per square inch.

Analysis Range:

C	Mn	Cr
.28 to .36	.44 to .64	.70 to 1.04

Progressive Effect

	Mo .20	Mo .40	Mo .76
Elastic limit	167,000	164,000	162,000
Elongation per cent in 2 in.	13.5	16.6	19.5
Reduction of area, per cent	52.0	58.4	61.0

For a constant tensile strength and very nearly constant elastic limit, the ductility of the steel is greatly increased by the addition of molybdenum from .20 up to .76. Conversely, of course, by employing suitable drawback temperatures, for a given ductility the elastic limit and tensile strength will show an increase in like manner.

The comparative effect of increased section on chrome-molybdenum and chrome-vanadium steels is shown by the following average results on different sizes of both, taken from tests on commercial stock.

Analysis Range

	C	Mn	Cr	V	Mo
Cr-V. ...	.23 to .30	.60 to .80	.70 to 1.00	.15 to .20	...
Cr-M. ..	.23 to .30	.60 to .80	.70 to 1.00		.25 to .35

The more complex quarternary alloy steels containing molybdenum show extremely high characteristics, as will be seen by reference to the following tables. Both of these steels can be drawn back to better than 1,000 degrees F. before the tensile strength falls below 200,000, and to 900 degrees F. before the elastic limit falls below this figure. The steel containing nickel exhibits remarkable physical properties at low drawing temperatures such as are employed in the production of oil hardened gears, whereas the steel containing vanadium possesses greater possibilities at the higher drawing temperatures.

	C	Mn	Cr	Ni	V	Mo
Chrome-nickel-molybdenum (1)	.44	.42	.99	2.04	...	.36
Chrome-vanadium-molybdenum (2)	.38	.60	1.00	...	.18	.80

Effect of Section

Size	Elastic Limit		Tensile Strength		Elastic Ratio		Elongation Per Cent		Reduction of Area	
	Ca-V	Cr-Mo	Cr-V	Cr-Mo	Cr-V	Cr-Mo	Cr-V	Cr-Mo	Cr-V	Cr-Mo
1 3/32 inch ...	134,200	134,800	153,200	156,200	87.6	86.2	16.8	16.8	57.1	59.0
1 1/8 inch	123,100	132,300	145,500	153,700	84.7	86.3	15.8	16.3	55.8	56.8
1 5/16 inch ...	116,900	133,500	150,300	153,200	77.7	87.1	15.1	16.8	53.2	56.5
1 11/16 inch ..	103,200	124,600	137,500	152,200	75.3	81.9	14.0	16.3	46.3	55.4

Sections, $\frac{7}{8}$ inch round (1), quenched in oil from 1,450 degrees F., and $1\frac{1}{8}$ inch round (2), quenched in oil from 1600 degrees F., both drawn as indicated.

Results of Tests on (1)

Chrome-Nickel-Molybdenum Steel

Drawing Temp. F.	Tensile Strength	Elastic Limit	Elongation Per Cent in 2 Inches	Reduction of Area Per Cent
400	336,600*	302,000*	10.0*	22.4*
600	275,000	241,000	11.3	43.0
800	240,000	220,000	12.0	46.0
1,000	204,000	185,000	15.0	51.0
1,200	152,000	134,000	20.5	61.0

*Section treated .505 inch round.

Results of Tests on (2)

Chrome-Vanadium-Molybdenum Steel

Drawing Temp. F.	Tensile Strength	Elastic Limit	Elongation Per Cent in 2 Inches	Reduction of Area Per Cent
600	243,000	217,000	9.0	38.2
800	225,000	207,000	10.8	45.4
1,000	210,000	197,000	14.0	52.5
1,200	186,000	174,000	18.2	59.7

A low carbon steel to which about $\frac{1}{4}$ per cent. molybdenum is added possesses extreme ductility which makes it particularly adapted in sheet form to the manufacture of pressed steel parts and at the same time when heat treated is capable of showing fairly high physical properties. Tests made on such a sheet steel, test piece— $1\frac{1}{2}$ inch wide by 9 inches long, follow:

Thickness of Sheet	Condition	Elastic Limit, Pounds per Square Inch	Per Cent Elongation in 2 Inches
5/32 inch	As rolled	45,640	44.5
5/32 inch	Quenched*	120,470	7.5

*Quenched in water from 1,600 degrees F. and drawn to 900 degrees F.

Analysis = C .164 Mn .45 Mo .226

Molybdenum steels also have the property of deep hardening, especially noticeable in the chrome-molybdenum series. Their properties are developed at higher drawing temperatures than employed with other steels, a fact directly related to their greater toughness and resistance to fatigue.

III. The Adaptability of the Steel to Fabrication.

It is in connection with this, the most important of all practical considerations, that the real commercial value of molybdenum is most evident. In the fabrication of an article from steel there are three fundamental operations:

1. Forging or cold pressing
2. Heat treating
3. Machining

Forging.

Good "forgeability" is determined by three prime factors: a. The manner in which the steel flows; b. permissible range in forging temperatures; c. the extent to which the scale adheres to the steel.

The molybdenum steels flow readily under the dies

and possess a wider safe forging range. It is in the ability to "throw the scale," however, that their chief advantage in forging lies. The scale on nickel and chrome-nickel steels adheres strongly to the bar, while that on the chrome-molybdenum comes off readily. Adhesion of scale during working naturally increases the prevalence of pits and other surface defects, hence aside from minimizing actual forging rejections the molybdenum steels show a smoother surface after hot working.

A loose scale such as that particularly characteristic of these steels is largely removed by the quenching operation during heat treatment, thereby eliminating pickling and hand cleaning of forgings before machining. Thus the general manufacturing difficulties due to scale are minimized.

Cold Pressing.

In sheet form, straight carbon molybdenum steel has proved to be, because of its great ductility, especially adaptable to parts which require extremely difficult forming operations. Also this steel can be treated to exhibit high strength and these qualities have made possible a much wider application of heat treatment to sheet metal parts than has heretofore been possible, as is indicated by the recent adoption of molybdenum steels by manufacturers of such commodities as automobile frames and implements such as shovels.

Heat Treating.

A wide, safe heat treatment range is another characteristic of these steels. In hardening, a temperature variation of 200 degrees F. is permissible, while in drawing, the properties fall off less rapidly and higher temperatures are used than with any other alloy steels.

A great deal of data has been published to show that the static physical properties of molybdenum steel are practically constant over a wide range of temperature for quenching. The following tests made under the supervision of Martin H. Schmid,* of the United Alloy Steel Corporation, show that dynamic properties as represented by the Izod impact test, are practically constant over a range of quenching temperatures of 500 degrees F.:

Analysis = C .27 Mn .66 Cr .83 Mo .42

Sections treated $\frac{7}{8}$ inch round. All drawn at 1,050 degrees F.

Quenching Temperature	Elastic Limit	Tensile Strength	Elongation Per Cent	Reduction of Area Per Cent	Brinell Hardness	Izod
1,500	140,000	163,500	18.5	62.7	319	58
1,600	139,500	161,700	17.0	63.1	321	62
1,700	138,400	160,400	17.5	61.7	321	60
1,800	138,300	158,500	18.0	61.5	319	61
1,900	139,600	159,600	16.8	57.9	317	56
2,000	140,000	157,000	17.0	59.0	317	55

While carelessness in heat treatment might result from an undue stressing of this point, the fact that

*Amer. Soc. for Steel Treaters (presented April, 1921).

the steels do possess this property is of material importance from the standpoint of the quantity producer. The high drawing temperatures mean greater ease in furnace regulation and the adaptability of the steel to heat treatment results in greater uniformity and fewer rejections.

For case hardened parts, molybdenum has the effect of greatly toughening the core and of adding hardness and wearing qualities to the case. It also has a very favorable effect as compared with nickel on the penetration of carbon in the carburizing process as is evidenced by the following table vouched for by Dr. Federico Giolitti:

	Proportion of Foreign Material	Velocity of Penetration in Tenths of a Millimeter
Nickel	2.0 per cent	7
Nickel	5.0 per cent	5
Molybdenum	1.0 per cent	9
Molybdenum	2.0 per cent	11

Machining.

Corroborative evidence from a large number of plants including several careful time study checks shows that for a specified elastic limit or Brinell hardness these steels machine much more easily than other alloys. As typical of this experience, the metallurgist of one of the foremost automobile companies in a recent report says:

"We have demonstrated that for a corresponding elastic limit or Brinell hardness, chrome-molybdenum steel machines much more easily than chrome-nickel and the nickel steels; * * * This quality can be made use of in one of two ways; either by producing parts of much greater strength and possessing a higher factor of safety, or by leaving the physical properties approximately the same as with other steels and effecting a great saving in machining cost and increasing largely the production in the machining departments."

IV. The Total Cost of the Fabricated Article.

These steels being commercially priced, the manufacturing advantages enumerated above make possible both increased production and decreased cost of the finished article.

Bearing on the purely commercial factors brought out in this paper, the following extract from a very exhaustive report by a well-known automobile production metallurgist is of interest:

"From a very careful consideration of the various alloys on the market, * * * we have come to the conclusion that at the present time the nearest approach to our ideal quantity production steel is one in which the alloying elements are chromium and molybdenum."

The automobile, for example, requires for its construction, steels of probably as wide a range of physical properties as any other familiar manufactured unit. The fewer kinds of steel necessary to meet its varied requirements, the obviously greater the efficiency in production, purchasing, inspection, etc.

Chrome-molybdenum steel of a single type in two or three carbon grades develops under suitable heat treatment a sufficient variation in physical properties to meet all of the demands of motor car construction. This fact has resulted in the adoption of molybdenum steel for the manufacture of all vital parts by some of the leaders in the automotive industry.

This standardization on molybdenum steels has effected the two-fold benefit of simplifying purchasing and inspection and of increasing manufacturing economy.

In order to give this subject the breadth that it deserves, the author has quoted results from various steel mills, but would like to mention here that his own experience in the production of molybdenum steels has confirmed a majority of the data presented.

Conclusion.

In 1905, this country produced a little over 20,000,000 tons of steel and less than 100,000 tons of alloy steel, a ratio in excess of 200 to 1. In 1910, this ratio was reduced to less than 50 to 1, and in 1919 to less than 25 to 1. Thus the production of alloy steel during this period has grown about eight times as fast as that of carbon steel.

For these reasons, the question of suitable alloys and particularly their availability for tonnage production, becomes of greater importance to the American steel manufacturer than ever before.

Besides carbon, silicon and manganese which may be termed fundamental steel alloys, not more than ten of all the known chemical elements have proven of value in steel making. From purely tonnage considerations, the commercial structural steels for moving and stationary parts, subjected to constant or suddenly applied loads, constitute the most important class of alloy steels. Only four of these ten alloying elements have been found to impart to steels of this class sufficient commercially advantageous properties to warrant their adoption. These elements are nickel, chromium, vanadium and molybdenum employed in various combinations.

Of all the alloying elements, molybdenum alone is found in sufficient quantities within our borders to take care of the requirements of the American steel industry. The war showed us this dependence upon foreign supply and the writer believes that, entirely aside from technical considerations, this fact alone is of sufficient importance to warrant the domestic industry in lending its support and coöperation to the development of this unique natural resource.

WHEELS FOR MOTOR TRUCKS.

The Bethlehem Steel Company, subsidiary of the Bethlehem Steel Corporation, has gone into the business of making steel wheels for motor trucks. The first unit of the plant to be used for this purpose is already in operation at Bethlehem, Pa. Sample wheels have already been produced and shown to truck manufacturers, who have shown much interest in the steel company's venture.

The company's new product is described as a structural steel wheel fabricated from specially rolled stock, which is punched, formed and bent in such a way that the flange of the channel becomes the rim of the wheel, while the spokes, shaped from the web, from an interlocking "keystone" hub construction.

"In other words," explains Automobile Topics commenting on the new wheel, "each length of channel stock is blanked out and formed into two pieces, from each of which the spokes project at right angles to the flanges. The spokes are then staggered, and finally the flanges are bent around into a circle, bringing the spokes into their final and proper relation. The ends of the rim are then welded. Two wheels are thus produced from each section of material."

New 18-Inch Continuous Mill

Mill Recently Completed by Whitaker-Glessner Company at
Portsmouth, Ohio, Modern In Every Respect.

ONE of the most modern continuous mills in the country has been recently put in operation at the Portsmouth Plant of the Whitaker-Glessner Company. By this addition the company have considerably increased their production of finished steel and are now in a position to further expand their rapidly growing plant, which normally employs more than five thousand men.

The mill was built by the Morgan Construction Company of Worcester, Mass., and consists of six (6) stands of 18-inch roughing and finishing rolls together with two (2) edging mills, located respectively in front of the first and third roughing passes. Provision is made for drawing loops between each pass when rolling sheet bar and by use of the edging rolls, they are permitted to roll sheet bar with good edges and accurate weight from slabs 12 inches wide and $2\frac{1}{2}$ inches thick to 10-pound bar without having to use tongue and groove passes. The shoes are so arranged that each mill can be lifted off separately and replaced with mills assembled, ready for rolling

blooms from 4-inch square to billets $1\frac{1}{2}$ -inch square—twisting guides being placed between each alternate pair of rolls.

The capacity of the mill is at present limited in production by the blooming mill but it is capable of producing 40,000 tons of 10-pound sheet bar per month.

Fig. 1 shows the mill assembled for rolling sheet bars. In the upper left-hand corner may be seen the skew approach table which was built by the Wheeling Mold & Foundry Co.—this table is provided with rollers 14 inches in diameter which are set at an angle with the centerline of the table. This arrangement enables the operator to quickly center the blooms on the table ready for the first pass as V grooves are cut in each roller 3 inches deep with sides sloping at 45 degrees. When the bloom is delivered to this table, it clings to the side guard while traveling, but just before it is cropped by the preliminary shear, the table is reversed and the bloom travels laterally across to the center where it drops into the V groove and is ready for the first pass. All of the

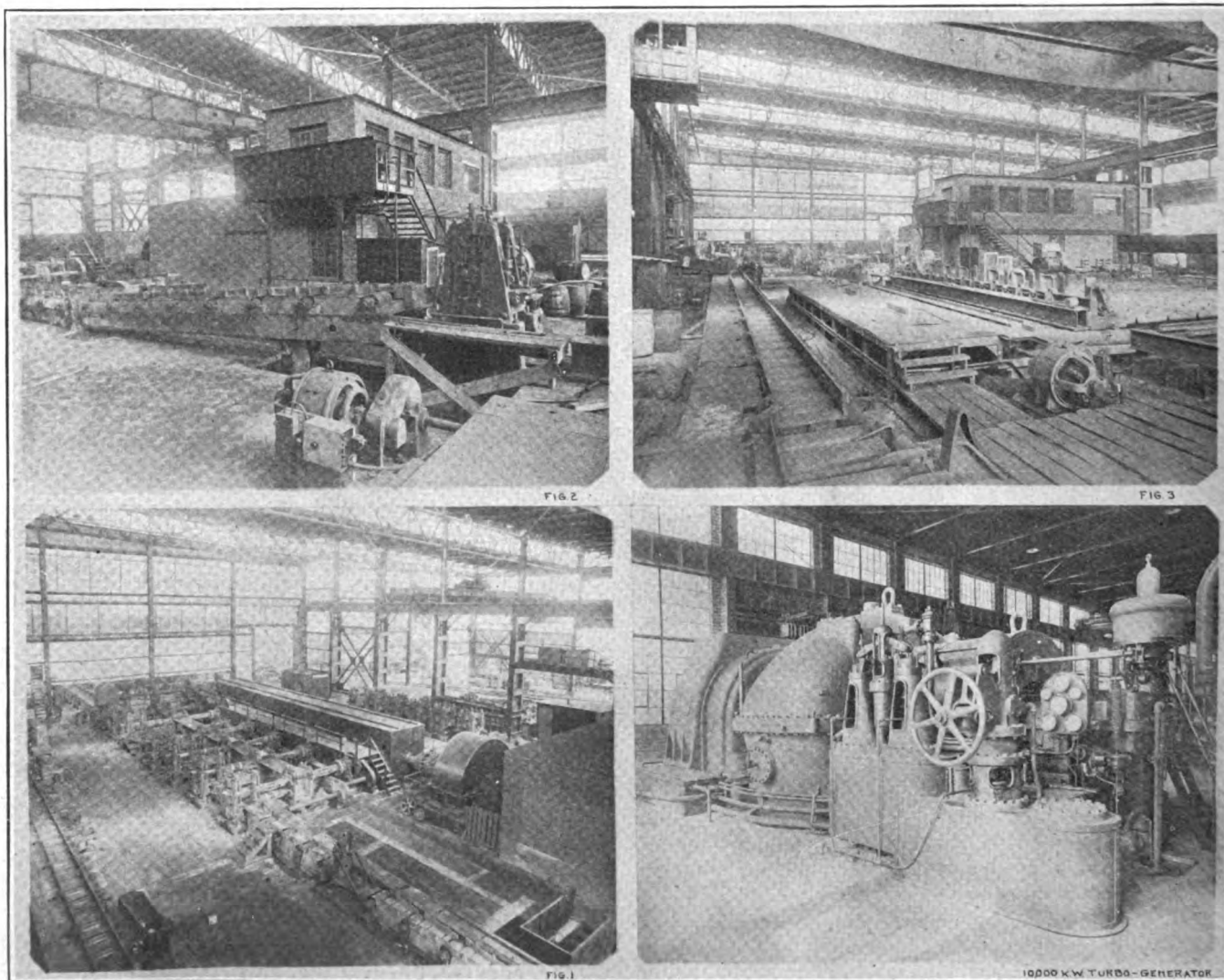


table gears are cut and run in oil—Hyatt bearing being used throughout.

The mill proper is driven by a 5,000 hp, 3 phase, 60 cycle, 2,200 volt motor at 440 rpm, which was built by the General Electric Company of Schenectady, N. Y. Both the motor and the control, is protected by a brick enclosure with a removable roof, which permits the use of overhead mill crane while making repairs.

The main drive was built by the Woodward Machine Company of Wooster, Ohio, and consists of a double helical pinion and gear unit which reduces the speed from 440 to 80 revolutions per minute. The forged steel pinion is cut integral with the shaft while the gear is of cast steel with split hubs held together with shrink rings. The gear cover is of cast iron made tight to permit the gears to run in oil and the bearings are connected with a Bowser Gravity Feed Oiling System, which lubricates all the mill bearings and mill pinions—these being built for oil lubrication only.

In the foreground may be seen an Edward-Carroll flying shear, which operates by steam—adjustment of the shear trip can be made on the shear table so that multiples of any desired length of sheet bar can be cut.

Fig. 2 shows the end of the shear table elevated to deliver sheet bar to the pinch rolls, which, in turn, deliver them to removable bar piler shown in Fig. 3. Here the sheet bars are stacked approximately 24 inches high and then removed by a lifting beam with six (6) hooks attached to the overhead crane, which conveys them to

the cooling bed shown in Fig. 4. When rolling billets, the end of the shear approach table is lowered level with the skew assembling table, from which the bar piler has been removed. This table has a capacity of 8000 pounds of 1½-inch billets and is provided with skewed rollers which group the billets of approximately 30 feet 0 inch lengths and delivers them by means of a straight edge to the cooling bed, which was also built by the Morgan Construction Company. This bed is 44 feet 0 inches wide and 80 feet 0 inches long and built of heavy rolled steel sections capped with cast iron wearing plates. Billets are pushed across this bed by means of tilting g-devils placed every 6 feet 0 inch at a speed of 188 feet 0 inch per minute to a piling bin located in the adjoining building in which the billets are weighed and then transferred to storage.

The 18-inch mill building is 103 feet 4 inches wide by 717 feet 0 inch long—in the lower end of which is located the sheet bar shears and picklers, which conveniently serve the furnace aisle of the sheet mill building.

In order to provide power to drive this mill and to take care of contemplated extensions, a 10,000 kw turbo-generator, built by the Westinghouse Electric & Mfg. Co., was installed, together with two (2) Stirling boilers of 823 hp capacity equipped with Westinghouse Electric & Mfg. Co. underfeed stokers. All of the necessary piping was supplied by the American Foundry & Construction Co. of Pittsburgh and the pipe covering by the H. W. Johns-Manville Company.

Calorizing as a Protection for Metal

Recent Developments As Applied to Steel, Copper and Brass—
Proper Methods of Use — Materials That Can Be Calorized.

By A. V. FARR,*

Vice President, Calorizing Company of Pittsburgh,
Pittsburgh, Pa.

BESIDES copper, calorizing has been applied to iron, steel, nickel, etc. The resistance to the action of heat has been characteristic of all these applications and today the greatest volume of calorized metal is iron and steel.

When it is considered that the loss of metals due to the action of heat runs into millions of dollars per year in this country, we recognize the importance of a process that reduces this loss. In recognition of his service to the world in inventing a means of preventing oxidation of metals at high temperatures, Mr. Van Aller was awarded the Franklin Institute Medal in November, 1918. Calorizing as practiced today has been considerably modified since Mr. Van Aller's early experiments and the following description is based upon standard methods as practiced under the General Electric Company patent rights.

It should be kept in mind that although calorized metal is more rust-resistant than is either iron or steel, that it serves quite a different purpose than does sherardizing or other galvanizing processes. Galvanizing is one of several means of protecting metals against

rust or corrosion at ordinary temperatures, whereas calorizing primarily protects metals against the action of heat.

It is well known that all metals in ordinary usage oxidize rapidly at temperatures higher than dull red. By high temperatures is meant such heat conditions as are to be found in the usual commercial heating operations, such as carbonizing, annealing, baking, boiling, drying, distilling, superheating, etc.

It should be understood that calorizing is a process applied to material already made, and serves the purpose of a protective coat. It is not a cast alloy and consequently there is no difficulty in applying it to thin sections, pipes, forged parts or very small pieces. In considering a surface coating to successfully resist heat the following conditions must be met: (1) the coating should be integral with the core or metal being protected (2) it should be able to withstand abrasion usually encountered in industrial service (3) it should not lessen the structural strength of the metal being protected and (4) it should not act as a heat insulator. Let us see how in calorizing these conditions are met.

To gain a better appreciation of the nature of the coat that constitutes calorizing, let us see how the coat is formed. The process of calorizing as most commonly

*Abstract of paper read before the Engineering Society of Western Pennsylvania, June 14, 1921. To be published complete in their proceedings.

practiced, consists in placing the material to be calorized in a rotary retort and heating in a reducing atmosphere, the retort being filled with a mixture containing finely divided aluminum. This treatment, conducted at high temperature, thoroughly infuses aluminum into the exposed portion of the metal being treated, so as to form a homogeneous aluminum alloy for a certain depth. This depth ranges from a few thousandths of an inch to the permeation of the entire mass, varying with the duration of the treatment and depending upon the service requirements of the material being processed. From this it is clear that calorizing is not a coating *on* the surface, but is *in* the surface of the material. In some cases where calorized trays are used to hold steel parts being heat-treated, the trays and contents are all quenched in oil or water. Such calorized trays are giving good service without cracking. This is as good an illustration of the cohesion between base metal and calorized coat, as could be desired.

The calorized surface is hard, in fact too hard to be readily machined or threaded. It therefore presents an excellent surface to withstand abrasion or wear. It is also much harder for a given furnace heat, such as cherry red, than is iron or steel at the same temperature.

The natural question that comes to mind is, "Why does calorizing protect metals at high temperatures?" The protection is due to the oxide formed by the action of heat on the protecting metal. This oxide, known as alumina, prevents the penetration of oxidizing gases to the metal being protected. The aluminum alloys with the metal, entering into solid solution with it. For this reason, should the outer surface become injured; the protective surface renews itself by forming a new oxide coating as far as the aluminum penetrates.

With reference to the third characteristic of a good protective coat—that it should not lessen the structural strength of the material being protected—let us consider the following:

In the process of calorizing, aluminum alloys with the metal without injury to the base metal. This is due to the fact that the aluminum enters into solid solution with the metal, forming a graded penetration. On the outside is alumina, which is the protective coat; next comes aluminum, which upon exposure to heat oxidizes to alumina or penetrates into the base metal forming more alloy; next is a band of aluminum alloyed with the base metal, which is very hard and which can be converted into the protective coat, should the outer coat be destroyed or worn through; and on the inside is the base metal unchanged except being annealed from the calorized process. This formation is clearly shown in one of the illustrations.

The following are physical tests on calorized steel tubing:

Test No.	Elastic Limit Lbs. Per Sq. In.	Ult. Strength Lbs. Per Sq. In.	Elong. 2 In. Per Cent	Elong. 8 In. Per Cent	Reduction of Area Per Cent
1	29,660	47,150*			51.6
2	28,750	45,310	30.5	23.0	42.9
3	26,290	49,020†	12.0		46.6
4	27,450	46,180	40.5	28.9	40.3
5	24,750	46,400	38.2	27.2	50.2
6	24,720	40,040	46.0	29.6	60.0

From this it is evident that the calorizing process gives results which compare favorably with those obtained by a soft anneal.

*Punch marks pulled off.

†Broke in grips.

The reduction of tensile strength due to calorizing is dependent directly upon the cross-sectional area of the part under consideration. For instance, on a ¼-inch rod, the percentage of cross-section which is affected by calorizing is obviously greater than in a 1-inch rod, so that the effect would show up more markedly on a ¼-inch rod.

What Can Be Calorized.

Iron, steel, copper, nickel, brass and, in fact, most metals can be successfully calorized. Although calorized cast gray iron has frequently given excellent results, it is safer practice to use white metal (white cast iron) or malleable cast iron, owing to the fact that the surfaces of same remain unchanged when subjected to heat, whereas gray cast iron "grows" upon continued exposure to heat. This growth in gray cast iron causes surface cracks to form, through which the oxidizing gases penetrate and attack the inner metal. White cast iron, being lower in carbon content, does not grow on exposure to heat and consequently the calorized (protective coat) is not broken by cracks and the inner metal is fully protected.

Cost of Calorizing.

Compared with other heat resisting processes, calorizing is not expensive. This economy is due to the fact that the calorized product is made up of a relatively inexpensive metal, such as iron or steel. The continuous protective coating of aluminum does not raise the total expense of the material to nearly the extent as would be the case if the product were made entirely of expensive material such as nickel, chrome or cobalt. The heat resisting cast alloys of chrome, nickel and iron in use today are far more expensive.

Because calorizing is ordinarily a surface treating process, the cost is based upon the number of square feet or exposed area. Size, shape and amount of material to be calorized in a given length of time are factors also brought into consideration in determining the cost of calorizing, just as in other heat-treating processes. It is safe to assume that the price of calorizing is materially reduced where a regular and large volume of material is involved.

Various Applications.

Iron, Steel and Metal—Retorts, carbonizing and annealing boxes, soot blower elements, furnace parts, etc. The increased life of calorized parts has been successfully demonstrated in a wide variety of applications and conditions.

Oil and Gas—Pressure still tubes for oil refining, valves, retorts, condenser tubes, etc. This has proved to be one of the largest fields of calorizing owing to the high temperatures encountered and the demand for continuous service without shut down.

Gas Engines—Valves, piston heads for Diesel engines, preheating coils, vaporizers, hot balls for ignition.

Carbon and Coke—Retorts, capsules, pipe and other high temperature parts.

Glass—Calorized metal as a substitute for clay parts in connection with hot molten glass. Parts where calorized metal is needed because it does not throw off streaks of rust as does ordinary untreated iron. Also pipe for conveying molten glass, furnace racks, stay bolts, etc.

Enameling—Furnace parts such as racks and points used to support material being enameled.

Miscellaneous—Oil stove burners, conveying appara-

tus, stoker parts, roasters, rotary dryers, kiln parts, muffle rolls, seamless drawn steel pots, furnace lining, baffle plates, etc.

Pyrometer Protection Tubes—Because pyrometers are used in such a wide variety of industries, they are deserving of special mention. The accuracy of a pyrometer depends directly upon the condition of the thermocouple. Unless the thermocouple is properly protected, the readings are inaccurate and the instrument worthless. Calorized pyrometer protection tubes are now sold as standard equipment by the various instrument companies and can be had by specifying them.

Thermocouples—Recent tests conducted on calorizing thermocouples indicate consistently satisfactory results. These thermocouples are used either with or without calorized protection tubes. The increased life of the couple

and the assurance of dependable pyrometric readings warrant the assumption that the use of calorized thermocouples is a growing one.

One of the most serious and costly phases of plant operation is the shut-down. Quite frequently this is caused by failure of a part subject to heat action. For example, a retort burns through, a tube in a still blisters badly and starts to leak, a metal support burns through and the material being processed is ruined, a thermocouple becomes badly oxidized and breaks off, throwing the pyrometer readings out; or a host of other sources of failure arise from a similar cause. The economy of calorizing as a factor in insuring continuous plant operation will stand very close scrutiny. On this basis alone the cost of calorizing is frequently the best invested money in a plant.

Color Classification of Blast Furnace Slags

Scientific Investigation on the Nature of the Slag Itself — Color
Classification of Slags of Value to Blast Furnace Men.

By WALLACE G. IMHOFF.

PART I.

1. Introduction.

BLAST furnace slag investigations have been conducted mainly from the commercial standpoint of utilization of blast furnace slags. Thousands of tons of slag are made annually as a by-product in the manufacture of pig iron, but only a small percentage of the total amount produced is reclaimed. Some of the most important uses that have been made of slag are as a foundation for paved streets (1), for railway ballasting (2), paving brick (3), concrete (4), and road making (5).

Scientific investigations on the nature of slag itself have been very limited. There are at least two reasons for this fact, namely: first, there are very few men thoroughly familiar with both the practical and theoretical side of blast furnace operation, and second, scientific investigations on slags to be of practical value must be made at the blast furnace itself and under the conditions present when slag is formed.

The characteristics of blast furnace slags were thoroughly understood by Mr. J. E. Johnson, Jr. (6). His articles published in the *Metallurgical and Chemical Engineering Magazine* and his book, "Blast Furnace Construction in America" (2), show that he was an authority on blast furnace operation and construction.

Other extremely interesting and valuable investigations have been made on the viscosity of slags by the United States Bureau of Mines (8). Numerous articles have appeared on slags, but very little work has been done in discovering the nature of slag, the features controlling its composition, how the individual components of the slag behave under different conditions, slag types, slag color, and many other interesting characteristics. In other words, very little has been done in the investigation of slag itself.

The writer, about ten years ago, decided to carry on research investigations on the blast furnace while employed as stove tender, water tender, and blower on furnaces supplying pig iron for the daily market.

After about three years of careful observations, in 1913 a table was worked out somewhat like short-hand and this code was used in making permanent records of blast furnace casts for the next four years. Photographs were made of the iron and slag to illustrate special features of interest.

Some of these investigations were described in a number of technical articles published in 1916 and 1917 (9), but, due to the war, the work was interrupted. These articles described various slag characteristics and illustrated clearly how they could be identified. In addition to careful observations on slag other features that effect the slag composition were investigated, such as extra coke (10), hearth temperature (11), stock, wind, fusion zone, top heat, and method of charging, all of which help to determine the final composition of the slag.

A glance over the field covered in the articles so far published show that the investigations cover a field where there are wonderful possibilities still untouched. This paper has been written for two purposes:

1. To furnish scientific data on "Molten Magmas" to the geologist.
2. To furnish the blast furnace man with a complete table of "Color Classification of Blast Furnace Slags."

This, I believe, is the first attempt that has ever been made to scientifically classify blast furnace slags. It, no doubt, has many weak points, but it is hoped as time goes on and other investigators add new data, that eventually the classification will be extremely useful to all practical blast furnace men.

2. Blast Furnace Slag as a Molten Magma.

a. The Nature of Blast Furnace Slag.

Blast furnace slags may be considered as very flexible molten magmas, ever changing in composition and produced under continually changing conditions of temperature and pressure. Ore, coke, and lime-

stone are charged in at the top of the furnace, and iron and slag are drawn out at the bottom. Blast furnace operation is the establishing of an equilibrium from a mass of variables producing in the final stage slag from the gangue of the ore, coke, and stone, and pig iron from the ores.

The slags are sometimes thin and fluid, sometimes thick and viscous, sometimes extremely hot, at other times extremely cold, and continually varying in composition. In the furnace they are at an extremely high temperature and under great pressure. Often, in fact, always, they contain some gases in solution and in a great many ways are similar to molten magmas found at different places on the earth.

That other investigators have noticed a similarity between slags and lavas is well illustrated by various references to slags in rock text books. Pirsson calls attention to the "slaggy" structure of a basaltic lava (12) and the two types of rock samples in the illustration are common slag samples seen on the blast furnace.

b. The Components of Blast Furnace Slag.

The average blast furnace slag is composed of silica, alumina, lime, magnesia, sulphur, iron, and manganese. In the past it has been considered simply as a slag, and the behavior of its components was studied mainly from the standpoint of fluxing out the impurities of the ore, coke, and stone, and thus producing a good grade of pig iron. The discussion herein submitted is from an entirely different viewpoint.

The writer has not been able to find any literature on blast furnace slags from the standpoint of a molten magma. Therefore, it is difficult to do more than try to outline some fundamental features which serve to explain some of the characteristics of slags, and thus in an indirect way lead to better furnace operation.

To begin with, there are a few fundamental known things, and from these we can at least derive material that more or less satisfactorily explains many other features. The first principle, which stands out prominently, is that temperature and slag composition are inseparable.

After carefully studying a large number of slags the idea developed that a slag is only a molten magma, and hence no doubt would exhibit some, or most of the characteristics of magmas. Each step in the investigations proved the theory proposed entirely possible so that the whole presents an excellent means of blast furnace control.

The first thing to consider then is the characteristics of the components that make up the slag, their color, their melting points, and their behavior under various changes of temperature and pressure.

These characteristics may be summarized in the following table:

Silica.....	Colorless.....	(SiO ₂).....	1600-1750° C. (13)
Alumina.....	Colorless.....	(Al ₂ O ₃).....	2050° C. (14)
Lime.....	White.....	(CaO).....	2570° C. (15)
Magnesia.....	White.....	(MgO).....	2800° C. (15)
Iron Oxide.....	Black.....	(FeO).....	1419° C. (16)
Sulphur.....	Pale Yellow.....	(S).....	120° C. (17)
Manganous Oxide.....	Olive Green.....	(MnO).....	White Heat (18)

c. The Variation and Mineral Composition of Magmas.

Kemp (14) states that the term magma is now generally employed for the molten masses of igneous

rocks before they have crystallized. He also says (20): "Of recent years we have come to regard molten magmas as essentially solutions of some compounds in others, and to appreciate that solutions do not cease to be such, even when the temperature is very high." Practically the same opinion is expressed by Chamberlin and Salisbury (21), which is as follows: "A molten magma is not to be viewed simply as a fused substance, but rather as a solution of one silicate in another, or as a solution of several silicates in one another mutually. The high temperature is to be regarded merely as a condition prerequisite to solution, or as the condition of fusion of some one constituent which then dissolves the others."

Clark (22), Pirsson (23), Leith and Van Hise (24), and many other geologists have described molten magmas and the writer has derived material for the present discussion from all these authors.

(1) Blast furnace slag as a foundation for paved streets. H. F. Brown. *il Eng. N.* 71:108-9. January 15, 1914.

(2) Blast furnace slag for railway ballasting. *il Plan Engineer.* 120:395-6 0 22. 1915.

(3) Manufacture of paving brick from furnace slag. *Eng. Rec.* 68:24. August 30, 1913.

Utilization of blast furnace slag for brick. *Iron Age.* 91:813. April 3, 1913.

(4) Blast furnace slag in concrete. W. A. Aiken. *Iron Trade Review.* 55:31-2. July 2, 1914.

(5) Utilization of iron and steel works slag. E. C. Brown. *Eng. Soc. W. Pa.* 31:884-96. January, 1916.

(6) The Operation of the Blast Furnace. Slags. By J. E. Johnson, Jr., *Met. and Chem. Eng.* April 1, 1916.

(7) Blast Furnace Construction in America. By J. E. Johnson, Jr. McGraw-Hill Book Company, Inc., 239 West Thirty-ninth street, New York, N. Y. 1917.

(8) Method of Measuring the Viscosity of Blast Furnace Slag at High Temperature. A. L. Field. U. S. Bureau of Mines. *Tech. Paper* 157. January 27, 1916.

(9) Conditions and Causes of Iron in Slags. By Wallace G. Imhoff. *Blast Furnace and Steel Plant.* August, 1916.

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Conditions and Causes of Iron in Slags. III. By Wallace G. Imhoff. *Blast Furnace and Steel Plant.* October, 1916.

Some Causes of Colors in Furnace Slags. By Wallace G. Imhoff. *Blast Furnace and Steel Plant.* February, 1917.

Types of Different Blast Furnace Slags. By Wallace G. Imhoff. *Blast Furnace and Steel Plant.* March, 1917.

Silica as a Component of Blast Furnace Slags. By Wallace G. Imhoff. April, 1917. *Blast Furnace and Steel Plant.*

Alumina as a Component of Furnace Slags. By Wallace G. Imhoff. *Blast Furnace and Steel Plant.* June, 1917.

Sulphur as a Component of Furnace Slags. I. By Wallace G. Imhoff. *Blast Furnace and Steel Plant.* July, 1917.

Sulphur as a Component of Furnace Slags. II. By Wallace G. Imhoff. *Blast Furnace and Steel Plant.* August, 1917.

Lime as a Component of Furnace Slag. By Wallace G. Imhoff. *Blast Furnace and Steel Plant.* September, 1917.

(10) Uses of Extra Coke on the Blast Furnace. By Wallace G. Imhoff. *Blast Furnace and Steel Plant.* January, 1916.

(11) How Tuyeres Indicate Furnace Conditions. By Wallace G. Imhoff. *Blast Furnace and Steel Plant.* July, 1916.

(12) Rocks and Rock Minerals. By Louis V. Pirsson. Plate 22. John Wiley and Sons, New York, N. Y.

(13) The Data of Geochemistry. By Frank Wigglesworth Clark. U. S. G. S. Bull. 695, p. 288.

(14) The Data of Geochemistry. By Frank Wigglesworth Clark. U. S. G. S. Bull. 695, p. 332, and *Jour. Washington Acad. Sci.*, vol. 3, 1913, p. 318. C. W. Kanolt.

(To be continued)

Deterioration of Coking Property of Coal

Experiments Described Which Were Made to Get More Definite Information Regarding Deterioration Effects of Different Degrees of Heating and to Determine a Rapid, Accurate Quantitative Test.

By WM. SEYMOUR.
Algoma Steel Corporation, Ltd.

THE deterioration of coal in storage has received much consideration by many but most of the work done has been with reference to the heating value and slight consideration has been given to coking property. The Algoma Steel Corporation, located at Sault Ste. Marie, Ont., Canada, must stock the winter's supply of coal (about 6 months' supply) in order to take advantage of water transportation from Ohio ports. The fact that heating, even not enough to start fires, caused deterioration of the coking property has been known for a considerable time and steps have been taken each season to keep this heating as small as possible by cross-cutting the pile, transferring the coal from the hot places, etc.

The objects of the experiments here described were: to get more definite information regarding the deterioration effects of different degrees of heating and to determine a rapid, accurate, quantitative test that applied to any sample of coal going to the ovens, would tell to what extent the coking property had depreciated.

The coals used are Cannelton, from the Cannelton Coal & Coke Co.'s mines in West Virginia, and Pocahontas, from the Superior mines of the same company in the same state.

Ultimate analyses on various samples, given in Table 1, as might be expected, show that the heated

Ultimate analyses						Ash free basis						
Percent	Percent	Percent	Percent	Percent	Percent	C	H ₂	N ₂	C ₂	S	H/O	
C	H ₂	N ₂	O ₂	S	Ash	Percent	Percent	Percent	Percent	Percent		
1.....	78.18	5.03	1.48	7.08	1.31	6.92	84.00	5.40	1.59	7.61	1.40	71.0
2.....	76.08	4.99	1.40	9.51	1.37	6.64	81.49	5.34	1.50	10.19	1.47	52.4
3.....	74.99	4.88	1.40	10.72	1.31	6.70	80.38	5.23	1.50	11.49	1.40	45.5
4.....	73.83	4.66	1.37	12.23	1.35	6.56	79.01	4.99	1.47	13.09	1.44	38.1
5.....	71.48	4.50	1.32	15.02	1.32	6.42	76.45	4.81	1.41	16.05	1.35	30.0
6.....	68.31	4.16	1.23	18.79	1.41	6.20	72.82	4.44	1.30	20.02	1.41	22.1

Table 1—Ultimate Analyses of Cannelton Coal.											
1. Cannelton coal from SS. Roberts (fresh).						3. From small piles left after cleaning up.					
2. Cannelton from large stock pile.						4. From heated stock pile.					
						Ash Free Basis					
	C	H ₂	N ₂	O ₂	S	Ash	C	H ₂	N ₂	O ₂	S
	Percent	Percent	Percent	Percent	Percent		Percent	Percent	Percent	Percent	Percent
1.	74.83	4.83	1.53	7.93	1.08	9.80	82.96	5.36	1.69	8.79	1.20
2.	74.28	4.33	0.37	11.27	1.15	8.60	81.27	4.74	0.41	12.33	1.25
3.	74.72	4.55	1.44	10.87	1.22	7.20	80.52	4.90	1.55	11.72	1.31
4.	73.90	4.44	0.10	10.02	0.74	10.80	82.85	4.99	0.11	11.24	0.81

Table 2—Heated Coal From Stock Pile.											
Sieve Test						Approximate analyses					
						Ash Free Basis					
						Volatile					
						Fixed carbon					
						Percent					
						Percent					
1.	On	¼-in. mesh	49.6			9.96	32.50	57.54	36.10	63.90	
2.	On	⅛-in. mesh	19.1			9.45	32.80	57.75	36.22	63.78	
3.	Thru	⅛-in. mesh	31.3			12.80	30.90	56.30	35.44	64.56	
4.	On	20 mesh	13.75			10.56	32.10	57.34	35.89	64.11	
5.	On	40 mesh	7.75			12.30	30.00	57.70	34.21	65.79	
6.	On	60 mesh	4.00			14.22	28.90	56.88	33.69	66.31	
7.	On	80 mesh	0.25			15.10					
8.	On	100 mesh	1.25			15.00	28.50	56.50	33.53	64.47	
9.	Thru	100 mesh	4.75			15.85	28.50	55.65	33.87	66.13	

Ultimate Analyses.												
C	H ₂	N ₂	O ₂	S	Ash	C	H ₂	N ₂	O ₂	S	H — O ratio	
Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent		
1.....	74.25	5.00	1.50	8.08	1.37	9.80	82.33	5.54	1.66	8.96	1.52	61.8
2.....	74.00	5.00	1.44	9.21	1.15	9.20	81.51	5.51	1.58	10.14	1.26	54.3
3.....	71.72	4.27	1.37	9.33	0.91	12.40	81.87	4.88	1.56	10.65	1.04	45.8
9.....	66.00	3.37	1.17	13.01	1.20	15.25	77.88	3.97	1.38	15.35	1.42	26.0

coal absorbed oxygen.

Because a much larger per cent of Cannelton is used the preliminary work was confined to the high volatile coal.

The first experiment was to select a sample of coal from the stock pile that we were fairly sure had been heated sufficiently to cause considerable deterioration. The sample was taken from a small ridge that had been left by the bucket when cleaning up. This ridge was about 4 feet at the deepest part and a thermometer inserted about 4 inches in the pile showed a temperature of 80 degrees C.

The sample as taken was screened and per cent of each size determined. Approximate analyses were made of each size and ultimate analyses of, sample 1, (on 1/4-inch mesh); sample 2, (on 1/8-inch mesh); sample 3, (thru 1/8-inch mesh); and sample 9, (thru 100 mesh).

These results are given in Table 2.

The "buttons" resulting from the standard volatile test were carefully observed as to coking property. We have adopted the following descriptions of these buttons as standard and will hereafter refer to them by number.

Coking property No. 1: good coke, swelling to two or three times the original volume of the coal, hard and with a metallic luster.

Coking property No. 2: good coke, slight swelling, quite hard, metallic luster.

Coking property No. 3: fair coke, no swelling, quite firm, slight metallic luster.

Coking property No. 4: poor coke, no swelling, maintains "button" shape, soft, black, no luster.

Coking property No. 5: coking property destroyed, falls apart upon removing from crucible, black, some adhesion, similar to fine wet sand pressed in crucible with finger then dumped out.

Coking property No. 6: remains as black powder.

The resulting buttons from the screened samples of stock coal are described as follows:

No. 1, on 1/4-inch mesh,	No. 2 coking property.
No. 2, on 1/8-inch mesh,	No. 2
No. 3, thru 1/8-inch mesh,	No. 4
No. 4, on 20-inch mesh,	No. 3
No. 5, on 40-inch mesh,	No. 5
No. 6, on 60-inch mesh,	No. 6
No. 7, on 80-inch mesh,	not enough for test.
No. 8, on 100-inch mesh,	No. 6 coking property.
No. 9, thru 100-inch mesh,	No. 6

These samples of coal have been retained and, together with the preceding results, have been used for reference and for comparison with the remainder of the work, which deals chiefly with artificially heated coal.

The first series of tests were made to determine the deterioration of coking quality of coal that had been subjected to various degrees of heat for varying lengths of time. A large sample of fresh coal was placed in an air-tight container and all of the following experiments have been made on portions of this sample.

The method of procedure was as follows, the coal is ground so as to pass a 100 mesh screen, 5 gm. samples are weighed into porcelain crucible lids and spread out with a spatula so as to expose a maximum amount of surface, the samples are then put into an air bath and a constant temperature maintained for the desired length of time.

Five tests were run at temperatures from 100 to 200 degrees C. by increments of 25 degrees. No. 1, heated from 0 to 5 hour at 200 degrees C., gave the following results:

No. of Sample	Time of heating hours	Increase in weight %	Coking property number
1	0	0	1
2	1	2.65	6
3	2	3.74	6
4	3	3.61	6
5	4	3.92	6
6	5	4.08	6

No. 2, heated from 0 to 4 hours at 175 degrees C., gave the following results:

No. of Sample	Time of heating hours	Increase in weight %	Coking property number
1	0	0	1
2	1	1.31	4
3	2	1.53	5
4	3	1.72	6
5	4	3.42	6

No. 3, heated from 0 to 5 hours at 150 degrees C., gave the following results:

No. of Sample	Time of heating hours	Increase in weight %	Coking property number
1	0	0	1
2	1	.22	3
3	2	.91	4
4	3	1.46	5
5	4	1.98	5
6	5	2.83	6

No. 4, heated from 0 to 12 hours at 125 degrees C., gave the following results:

No. of Sample	Time of heating hours	Increase in weight %	Coking property number
1	0	0	1
2	2	2.02	4
3	4	1.96	4
4	6	2.76	4
5	8	3.00	5
6	10	3.76	5
7	12	5.10	5

No. 5, heated from 0 to 11 days at 100 degrees C., gave the following results:

No. of Sample	Time of heating hours	Increase in weight %	Coking property number
1	0	0	1
2	2	1.94	2
3	4	3.14	3
4	6	3.90	4
5	11	4.30	5
6	11	7.82	

Note: No. 6 was a special test run for 11 days at 125 degrees C.

In addition to the button tests and increase in weight an ultimate analysis was made on each sample.

This test is worthy of careful consideration. It shows very clearly the decided increase in oxygen. The hydrogen-oxygen ratio drops rapidly, at 4 days being below the point which is considered necessary by White for a good coking coal (Effect of Oxygen in Coal, by David White, Bureau of Mines Bulletin 29, 1911).

The results of these tests show conclusively that even with a temperature as low as 100 degrees C., the coking property will, under favorable conditions, be destroyed in a short time. Conditions in the storage pile differ from those of the tests in that: (1) Much of the coal is lump, (2) air does not have free access to all of the coal, and (3) the storage pile has

a large amount of water vapor while the air bath of the tests was practically free from vapor. While further work along the above lines would undoubtedly be of interest and value, it was decided at this point to work on the second objective, namely the determination of a rapid, accurate, quantitative test to determine the percentage of deterioration.

Consideration of the ultimate analyses indicates that the oxygen content or the hydrogen-oxygen ratio might, upon study, give accurate information as to deterioration. The objections to any method based on ultimate analysis are: (1) the expensive apparatus necessary, (2) the time required, (3) the skilled manipulation necessary and (4) necessity for careful checking.

Many attempts were made to discover a test that would cover all requirements. Most of them were based on the theory that if the maximum amount of oxygen that a sample of fresh coal would absorb could be determined, this determination applied to a given sample would show to what extent it had absorbed oxygen before the test was applied and, consequently, the amount of deterioration. Some of the experiments made gave no results, others were rejected on account of insufficient accuracy. Of the latter, oxidation with nitric acid was one of the most promising. One gram of coal, ground to pass through a 100-mesh screen, was weighed into a porcelain crucible, 2 cu. cm. of concentrated HNO_3 run in carefully from a burette, thoroughly stirred with a glass rod, allowed to stand 10 minutes, diluted with cold water, filtered, washed, filtrate titrated, and amount of acid used calculated. A large number of tests were made in this manner and checked up fairly well with coking tests, etc., but the method was finally rejected as not sufficiently accurate.

In some of the experiments with coal, it was noticed that treatment of heated coal with caustic potash or ammonia gave a liquor with a brownish color, the depth of color apparently depending on the degree of deterioration of coking property of the coal. It was also noticed that fresh coal, similarly treated, gave no color. In order to prove that this color is not due to iron in the coal, the sample was washed with HCl , then with water, and treated with caustic; the same brownish color remained in the filtrate. We then developed a color comparison test and all our work so far warrants the assumption that this method fills the requirements of our second objective.

The method of procedure is as follows: Sample (as taken, not dried. If moisture is to be considered separate determination must be made for same) is ground to pass through 100-mesh sieve. Five (5) grams is weighed into a flash or breaker, 100 cu. cm. of dilute (1 part acid to 10 parts water) hydrochloric acid added, mixed thoroughly, boiled a few minutes and filtered on an asbestos plug with suction. Residue is washed with hot water and filtrate discarded. Rinse filtering flask thoroughly replace and wash residue remaining on asbestos plug with boiling normal caustic soda, about six washings (enough to wash out color thoroughly) totaling about 50 cu. cm. The filtrate, if colored, is diluted to 50 cu. cm. and compared in Nessler tubes with a standard color. In comparing the colors the standard is diluted so as to match the color being tested and per cent of dilution observed.

It was necessary to establish a standard. For this purpose sample No. 6 of the heated coal from stock

pile, which was the portion remaining on a 60-mesh screen, was selected and arbitrarily assumed to be 100 per cent non-coking. Efforts have been made to duplicate this color with a known mixture but they have not been successful. It has been reproduced by heating fresh coal, ground to pass a 100-mesh screen, in an air bath at 150 degrees C. for a length of time sufficient to make it non-coking when tested in a crucible. Without doubt a tintometer could be made up to serve the purpose.

For eight months, April, 1920 to November, 1920, inclusive, daily tests have been run on the mixed coal to the ovens and the results of these tests have been plotted together with the daily coke per ton iron on the blast furnaces. Considering the other factors entering into blast furnace operation the similarity of these curves is remarkable.

Consideration of the increased coke per ton iron and the loss of by-products at the ovens shows that the financial loss due to oxidized coal may be enormous.

How may this loss be prevented? Much has been written upon the stocking of coal to prevent segregation, etc. and care in this regard will undoubtedly effect a considerable saving. But careful consideration of the sample of heated coal from stock makes it appear that the loss might be eliminated by screening the coal at the stock pile, stocking the lump and using the fines as soon as possible.

These experiments show the importance of getting coal into the ovens before it has undergone any chemical changes due to exposure to the atmosphere and it might be possible that, with the poor coking coals, it would pay to locate the ovens at the mines.

LATE DEVELOPMENTS IN THE BASSET DIRECT STEEL PROCESS.

The latest developments in the Basset direct process for steel in France are recounted by the French correspondent of the *London Ironmonger*, in its issue for May 7, as follows:

The experimental stage in Lucien Basset's process for the production of iron, steel and pig iron direct from ore in the rotary furnace is said consisting of twelve 250-ton furnaces, on the edge of the iron mines of Normandy, capable of producing 3,000 tons of metal per day, will begin to be constructed in the course of a month. The cost of production, it is claimed, will be only 110 francs per ton, a figure which seems incredible in view of the fact that ore alone today is between 20 and 30 francs per ton, and the cheapest coal obtainable from 90 to 100 francs per ton. M. Basset also states that each furnace will cost only 2,500,000 francs to erect, compared with the 42,000,000 francs required for the erection of blast furnaces or an open-hearth plant of like capacity. The erection of the plant, he says, has been decided upon after the success obtained recently at Dennemont, near Mantes, first with 25-ton and then with 100-ton furnaces, in which rail-quality steel has been successfully produced. M. Basset's unwillingness to permit inspection of his plant throughout his experiments has, not unnaturally, created a good deal of skepticism on the Continent, and the claims made for his process are not yet taken very seriously by steelmakers. Should his promises be fulfilled and steel be placed on the market at a price which is even less than that ruling in pre-war days, and at only a quarter of the present quotation, a revolution will indeed be brought about in metallurgy.

Analysis of Wholesale Electric Costs

Graphic Charts Which Facilitate the Analysis of Light and Power Costs.

By F. M. VAN DEVENTER.

SYNOPSIS: *The preceding article presented a graphic chart for the solution of costs and unit rates for electric power purchased under Duquesne Light Company's wholesale power schedule "F." The present article presents a similar chart based upon the West Penn Power Company's wholesale power schedule "J." The article contains an explanation of the chart and of one of its principal uses. The third article will embody a general consideration of the "demand plus energy" system of rates, and an analysis of the consumers' power conditions which affect the cost of the service.*

ARTICLE II.

WHEN power was purchased under a unit rate per kwh, the rate being a definitely fixed quantity for each user, depending upon whether he were a small domestic consumer or a purchaser of power in "wholesale lots," it was an easy matter to check the monthly charge for power, by merely multiplying the quantity of energy metered by the unit rate. Similarly an estimator or engineer who was confronted with a problem which involved the power charge for operating a piece of proposed equipment knew what the unit energy rate would be, without any calculation.

The present-day "demand plus energy" schedules, however, entail considerable complication, as the unit rate to a particular consumer changes from one month to the next, depending upon the nature of the load curve; and a more or less extensive calculation must be made to check a power bill or to determine the unit rate under any assumed condition.

The West Penn Power Company's schedule "J" for wholesale light and power is a good example of this type of rate. The several paragraphs which fix the cost service are essentially as follows:

LARGE POWER RATE.

(Available for Alternating Current Service.)

SCHEDULE "J."

RATE.

For the kilowatt hours of electric energy delivered per month up to the amount corresponding to seventy (70) hours use of consumer's demand, six (6) cents gross per kilowatt hour.

For remainder of electric energy delivered during same month, one and one-quarter ($1\frac{1}{4}$) cents gross per kilowatt hour.

CONSUMER'S DEMAND.

Consumer's demand will be based upon the significant peak created at each service connection and will be determined for each class of service by application of the provisions hereinafter contained.

The significant peak will be the amount of power equivalent to the maximum average kilovolt amperes drawn for a period of five consecutive minutes during any billing month, plus fifty (50) per centum of that part of any single operating peak created during the same billing month which is in excess of one hundred fifty (150) per centum of such maximum average for a five minute period.

The significant peak may be determined at option of producer, as follows:

- By calculation from Table No. 1 constituting a part of this Schedule.
- By calculation from a registration of ampere measuring devices only, it being assumed that the nominal voltage is constant.
- By registration in kilowatts; for which purpose indicating instruments showing average conditions may be used.
- By concurrent measurement or registration of the kilowatts and wattless component of the electric energy drawn.
- By concurrent measurement or registration of ampere and voltage measuring devices.

* (Method c. is customarily used by this company. A kw record is obtained from a curve-drawing meter; the significant (5-minute) peak and the instantaneous peak are observed from the curve, and the demand thus obtained is corrected for power factor to give the kv-a demand.)

Notes:

- In determining the significant peak any five-minute average or single operating peak created during off peak hours, as hereinafter defined, will be taken at fifty (50) per centum of the actual amount of such peak or peaks; provided, that consumer shall submit proof satisfactory to producer of the time such peak or peaks were created.

CLASSES OF SERVICE.

- General services entitles consumer to power during all hours and consumer's demand will be the full amount of the significant peak calculated or measured in kilovolt-amperes, except when consumer so operates as to earn line regulation discount, in which event the significant peak will be calculated or measured in kilowatts.

- Off peak service entitles consumer to power during off hours and consumer's demand will be twenty-five (25) per centum of the amount of the significant peak calculated or measured in kilovolt-amperes. In consideration of the low charge for this class of service, consumer will not be entitled under any circumstances to power except during off peak hours and producer may at its option cut off the energy during all other hours.

OFF PEAK HOURS.

Off peak hours, as used herein, are from 5:00 P. M. until 7:00 A. M. daily, from 12:00 noon Saturday until 7:00 A. M. Monday; and all day holidays generally observed.

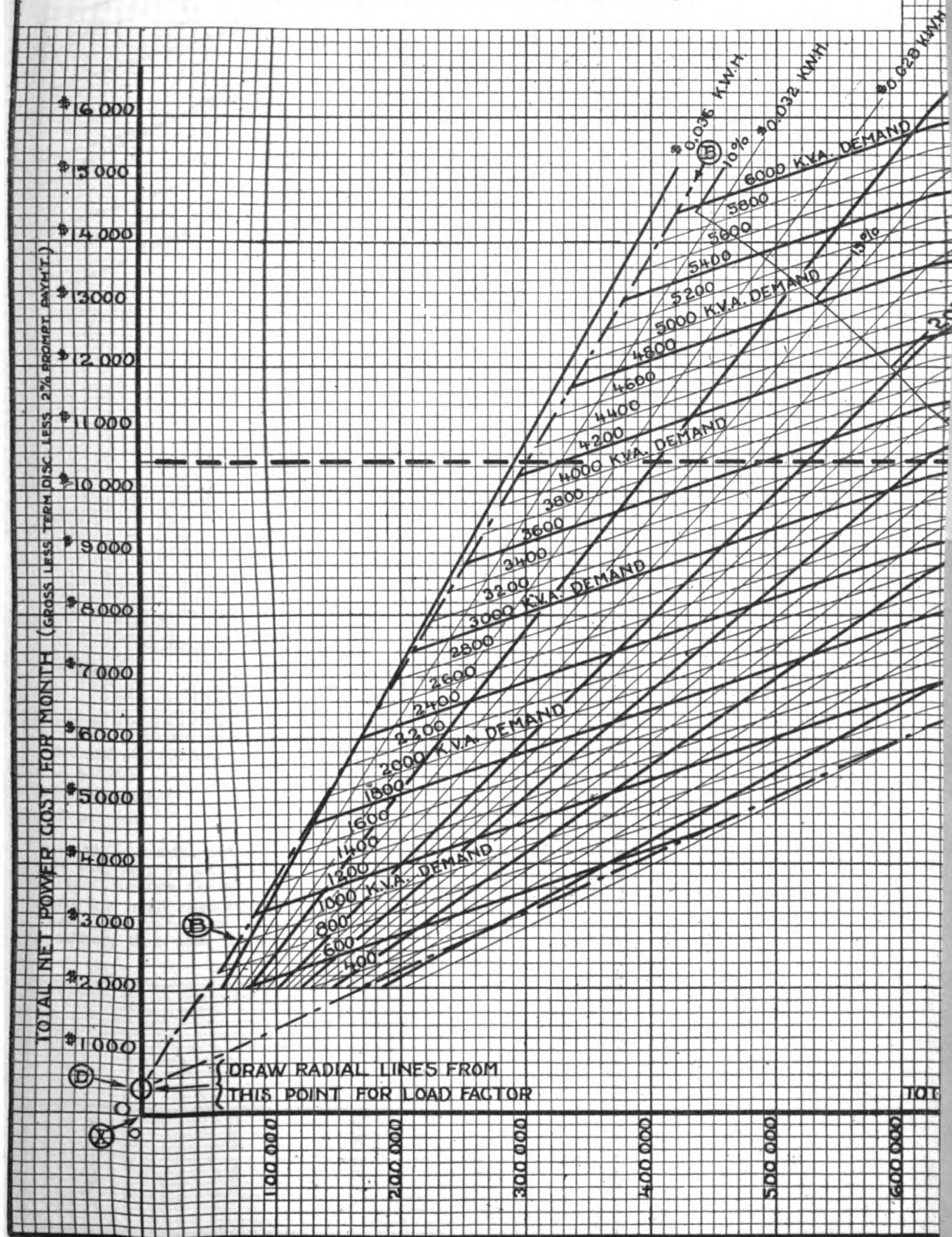
MINIMUM CONSUMER'S DEMAND.

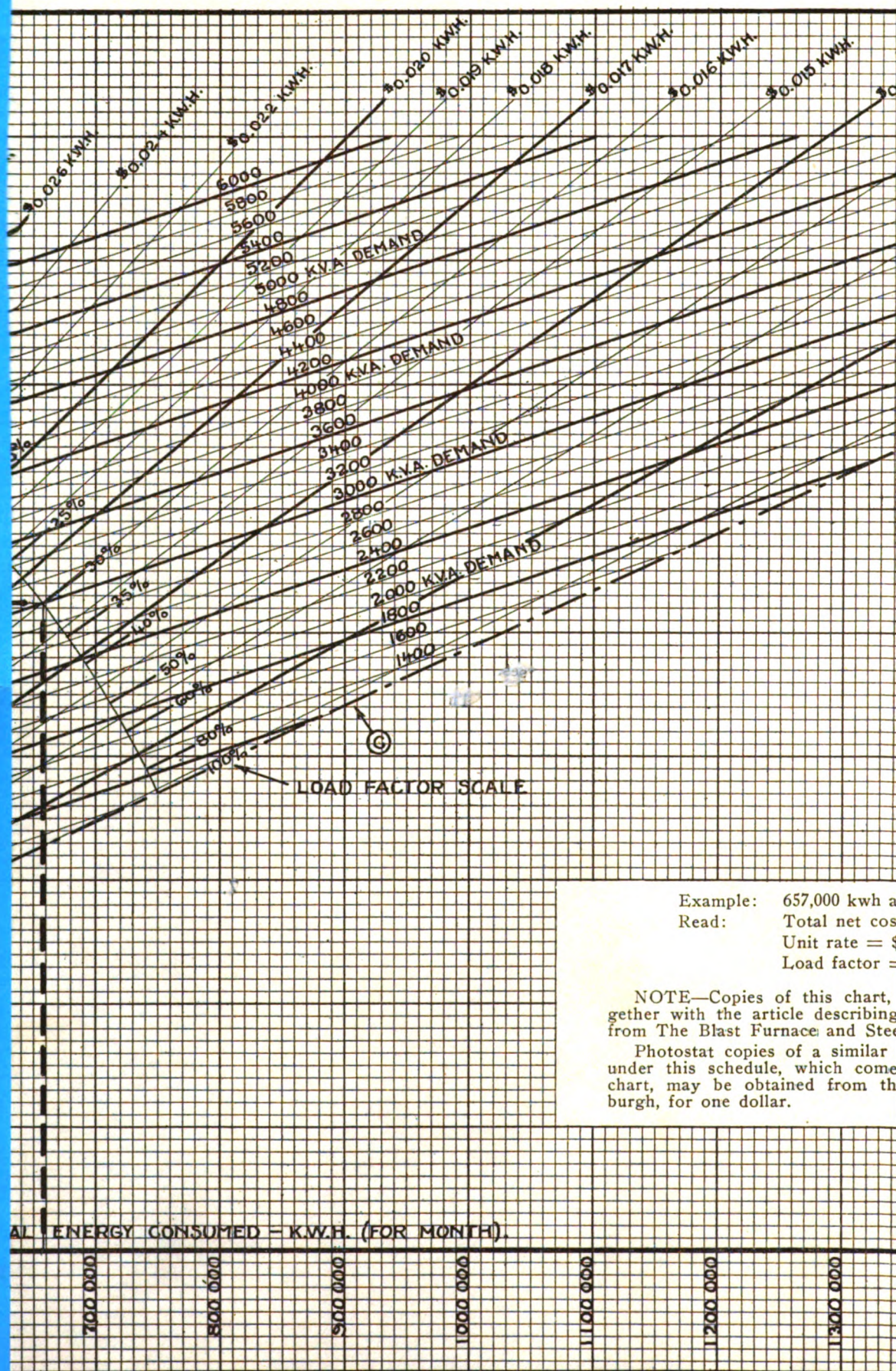
Minimum consumer's demand for each service connection will be one (1) KV-A.

To compensate for the capacity required to supply varying demands, the minimum consumer's demand, for any month will be fifty (50) per centum of the highest demand, established for any month within the eleven months last preceding, except in case of permanent material reduction in consumer's installation; provided, however, if consumer has a number of service connections so located that the charges for service delivered thereto may be aggregated, as hereinafter provided under paragraph "Term Discounts," the aggregate demand, i. e., the sum of the consumer's demands for each service connection, will be used in the application of this provision and the minimum aggregate demand will be seventy-five (75) per centum of the highest aggregate demand for the same service connections established for any month within the eleven months last preceding; and the primary rate of six (6) cents per kilowatt hour shall apply to the aggregate net amount of energy consumed up to an amount equal to seventy (70) hours use of seventy-five (75) per centum of such maximum aggregate demand.

* Author's note.

Graphic Determination of Wholesale Power Costs and Rates
 For Large Power Consumers
 Based Upon West Penn Power Company's Schedule "J"
 Revised March 1, 1921
 Copyright, 1921, by F. M. VanDeventer, Pittsburgh.





SYSTEM VOLTAGE DISCOUNTS.

(a) Where electric service is furnished by producer from a distributing system having a voltage between one thousand (1,000) and fifteen thousand (15,000) volts and consumer purchases electric service at the system voltage, thereby relieving producer from transforming obligation and expense, a deduction of five (5) per centum of the total kilowatt hours of electric energy delivered at such system voltage will be made before calculating charge to consumer.

(b) Where electric service is furnished by producer from a distributing system having a voltage above fifteen thousand (15,000) volts and consumer purchases electric service at the system voltage, thereby relieving producer from transforming obligation and expense, a deduction of ten (10) per centum of the total kilowatt hours of electric energy delivered at such system voltage will be made before calculating charge to consumer; provided, that for reasons of safety producer may refuse to supply electric service from or to allow service connections to be made to systems having voltage of fifteen thousand (15,000) volts or more.

LINE REGULATION DISCOUNTS.

(Not applicable to off-peak service.)

a. Where consumer constantly maintains leading power factor of ninety (90) or less per centum, at any service connection, a deduction of five (5) per centum of the total kilowatt hours of electric energy delivered by such service connection will be made before calculating charge to consumer.

b. Where consumer, during all hours of operation, by the use of automatically regulated synchronous apparatus of sufficient capacity to maintain a leading power-factor of ninety (90) per centum at any service connection under normal operating conditions, regulates the voltage of producer's service to the fullest capacity of such apparatus, a deduction of five (5) per centum of the total kilowatt hours of electric energy delivered by such service connection, will be made before calculating charge to consumer.

TERM DISCOUNTS.

Where electric service is furnished consumer under guarantee to take service for a term of one (1) year or longer in accordance with rules and regulations of producer, block discounts shown below will be allowed for each metering point on energy charges calculated from above rates; provided, however, if consumer has a number of service connections into one premises or operation, or which could be economically connected by consumer's own transmission line, charges for electric service delivered under this schedule to all of such service connections shall be aggregated and such block discounts applied to the total sum of energy charges of the separate service connections.

BLOCK DISCOUNTS.

(To be calculated on the basis of billing month.)

First \$100.00—Net	Next \$200.00—18 per cent
Next 100.00—2½ per cent	Next 200.00—21 per cent
Next 100.00—7½ per cent	Next 200.00—25 per cent
Next 100.00—10 per cent	Next 200.00—29 per cent
Next 100.00—12 per cent	Next 200.00—33 per cent
Next 100.00—15 per cent	Next 200.00—38 per cent

All amounts in excess of \$1,800.00—43 per cent.

MINIMUM CHARGES.

The minimum monthly gross charge to be paid by consumer will be an amount equal to twenty-five (25) hours' use of maximum consumer's demand at any time established subject to the following provisions:

- A measured consumer's demand will take precedence over that previously established by application of Table No. 1.
- The minimum monthly charge will not be less than an amount equal to twenty-five (25) hours' use of:
 - Fifty (50) per centum of the kw capacity specified in the proposal covering the service connection effective after producer has installed its facilities necessary to furnish electric service.
 - The rated capacity of consumer's largest connected motor or piece of apparatus.
 - The rated capacity of the transforming apparatus installed on the service connection when the service required is of such character that excess transforming capacity is necessary to

supply instantaneous or momentary operating peaks.

In calculating all minimum charges the gross rate of six (6) cents per kilowatt hour will be used subject to prompt payment discount only; term discounts are not applicable to minimum charges.

PROMPT PAYMENT DISCOUNT.

A discount of two (2) per centum will be allowed on the monthly bill if paid in full on or before the tenth (10) day after that on which bill is rendered.

In determining amount of any discount only two decimal places will be employed in case of money and the nearest unit in case of energy.

RIDER TO SCHEDULE "J" FOR LIMITED SERVICE.

Limited service entitles consumer to power during all hours, except for such temporary periods as may be prescribed by producer, by reason of reduced or insufficient capacity of producer's facilities, in accordance with the terms and conditions hereinafter contained. The supply of limited service grants a priority for continuous power service, except in cases of emergency, to consumers supplied with general service under Schedule "J," the provisions of which shall obtain except as they are modified by the terms and conditions of this rider and of the proposal for limited service.

(a) Limited service is available only to consumers creating in normal operation significant peaks of not less than 500 kw, and it will be supplied and significant peak and energy will be metered only at system voltages above 15,000 volts.

(b) Consumer's demand will be seventy (70) per centum of the amount of significant peak, calculated or measured in kilovolt-amperes as provided in Schedule "J," provided, however, that consumer's demand shall be fifty-eight (58) per centum of such significant peak for any billing month during which producer shall notify consumer to curtail or shut off entirely the power supply, for other than emergency cause, on more than five (5) days.

(f) The minimum monthly gross charge to be paid by consumer will be an amount equal to one dollar and twenty-five cents (\$1.25) per kv-a of the maximum significant peak at any time created, subject to the limitations enumerated in Schedule "J" under paragraphs 1, 2 and 3 of Section b. of "Minimum Charges." The minimum monthly charge is not subject to term block discounts.

Problem C

An example of the standard method of calculation follows:

Determine the cost of 65,000 kwh at a maximum demand of 3,000 kva.

DETERMINATION OF QUANTITY BLOCKS.

First Block:

70 hours' use of the maximum demand:

$$70 \times 3,000 = 210,000 \text{ kwh (A).}$$

Second Block (difference):

$$657,000 - 210,000 = 447,000 \text{ kwh (B).}$$

DETERMINATION OF COST.

210,000 kwh at \$0.06 =	\$ 12,600.00
447,000 kwh at \$0.0125 =	5,587.50

Total gross cost..... \$ 18,187.50

Discount:

On \$1,800*	\$ 375.00
43 per cent on \$16,387.50 (difference)	7,046.62

Total discount \$ 7,421.62

Gross less term discount..... \$ 10,765.88

Less 2 per cent for prompt payment. 215.31

Total net power cost..... \$ 10,550.57

*Obtained by integrating the eleven block discounts up to and including \$1,800.00.

Equation Form

The complicated wording of the contract can be stated much more simply in equation form, but the amount of calculation required to solve a problem is the same by either method.

Let D = maximum demand, kva†
Let E = total energy metered (month) kwh

Then:

Total gross cost = $(4.2 D) + .0125 (E - 70 D)$
Term discount = 0.43 (gross — \$1,800.00) + \$375.00
Total net cost = 0.98 (gross less term discount)

The preceding formulae apply only for load factors exceeding 9.6 per cent, or in the portion of the chart to the right of line "B." Below 9.6 per cent load factor use the equation: Cost = $.0335 \times \text{kwh} + \382 . The bill calculated by this formula may be less than the minimum charge, in which case the latter applies.

Graphic Determination of Cost

The accompanying chart (for large consumers) was designed with two purposes in view: First, to facilitate the checking of power bills by means of a chart instead of by calculation; and, second, to put the conditions of the contract into such form as to allow a visualization of the terms, and of the effects of the several factors which affect the cost of the service. The latter phase will be reserved for a later article. The first phase will be demonstrated after the construction and use of the chart have been explained.

There are five variables represented on the chart: kwh consumed, monthly power cost, demand, rate per kwh, and load factor. Each variable is represented by a "family" of lines, and if any two of the five variables are known, the intersection of the lines representing the particular values of the variables determines at once the other three variables. Vertical lines are lines of constant energy consumption; horizontals are constant monthly costs; constant demand lines are parallel to each other and have a slope of about 20 degrees in the major portion of the chart. The constant unit rate lines are radii from the intersection "X" at the lower left-hand corner of the chart, and are marked, e. g., \$0.011 (per) kwh. The constant load factor‡ lines are also radial, but it is unfortunate that their center is so near and yet not co-incident with the center of the other radial lines. For this reason these lines are not drawn on the chart, but are indicated by a load factor scale. Any load factor line is determined by the value on the scale and the common point "D." A ruler or other straight-edge may be placed to represent any load factor line, but it is suggested that if the user of the chart makes frequent reference to this variable, that the lines be drawn with red ink.

Two other lines are significant. The dot and dash line "B" marks the division between the first and second quantity blocks, and represents 9.6 per cent load factor, since the first quantity block is 70 hours use of the demand, and one month = 730 hours. $70 \div 730 \times 100 = 9.6$ per cent. The significance of this line and the blank area to the left of it will appear in problems D and E. Line "C" is the 100 per cent load factor line, and marks the normal

†This may be determined by any of the several methods which depend upon the class of service. The controlling value is always indicated on the bill.

‡The term "load factor" is used in these articles in the sense as defined by the A. I. E. E., i. e., the ratio of average load to maximum load.

boundary of the chart, because in order to have an actual load factor of 100 per cent, the maximum demand must be carried continuously throughout the entire month. A peculiarity of this schedule, however, is that consumers who purchase power under the "off-peak" or "limited" service clauses may have an "apparent load-factor" greater than 100 per cent. This is because under the terms of these clauses, the billing demand is taken as a fraction of the metered demand. For example, suppose 730,000 kwh are used on a metered demand of 2,000 kva. The actual load

factor = $\frac{730,000 \div 730}{2,000} \times 100 = 50$ per cent. But

for off-peak service the billing demand is taken as 25 per cent of the metered demand, which in this case is $2,000 \times .25 = 500$ kva. The apparent load

factor = $\frac{730,000 \div 730}{500} \times 100 = 200$ per cent.

Similarly for "limited" service, the billing demand is taken as 70 per cent of the metered demand, and a similar result is possible. Such cases, however, are exceptions to the general rule, and it was not deemed advisable to extend the range of the chart beyond 100 per cent load factor. In such instances, the chart can be used by extending the demand line affected to the right until the necessary point is reached.

Example

For a working example in the use of the chart, suppose the following bill is rendered, and is to be checked:

(It will be noted that this is the same as problem C.)

9-24-21	1,893,500
8-24-21	1,236,500
	657,000 kwh consumed
(Demand = kva 3,000)	
210,000 kwh at \$.06 =	\$ 12,600.00
447,000 kwh at .0125 =	5,587.50
	\$ 18,187.50
Quantity discount	7,421.62
	\$ 10,765.88
Subject to 2 per cent discount as	
per amount deducted provided	
payment is made on or before	
April 4, 1921.....	208.32
	<u>\$ 10,557.56</u>

The given conditions are: 657,000 kwh and 3,000 kva demand. Starting at 657,000 kwh on the lower scale (energy consumed) follow vertically until the 3,000 kva demand line is intersected. This intersection determines the significant point from which all the unknown quantities may be determined. Following horizontally to the left, the power bill is found to be about \$10,490, which checks within one-half of one per cent with the bill as rendered. If the unit rate is desired, it is seen that the significant point falls exactly on the \$0.016 line; hence that is the cost per kw hour. Further, a straight edge placed so as to intersect the circle "D" and 30 per cent on the load factor scale, also intersects the significant point, hence the monthly load factor was 30 per cent.

Problem D

In cases of such low load factor that the energy

consumed is less than 70 hours use of the demand, the significant point falls on line "B" and depends only upon the energy consumed.

This is illustrated by: 218,000 kwh at 3,800 kva demand. It will be found that a vertical line from 218,000 kwh does not intersect the 3,800 kva demand line, hence the significant point is determined by the intersection of this vertical with line "B." Following to the left from this point, the cost is estimated as \$7,700. (The calculated value is \$7,697.51.)

Problem E

The location of an error when a bill does not check is demonstrated by the following:

9-24-21	6,176,000
8-24-21	5,236,000
940,000 kwh consumed	
(Demand = kva 3,200)	
352,000 kwh at \$.06 =	\$ 21,120.00
588,00 kwh at .0125 =	7,350.00
	\$ 28,470.00
Quantity discount	11,843.10
	\$ 16,626.90
Subject to 2 per cent discount as	
per amount deducted provided	
payment is made on or before	
April 4, 1921	
	332.54
	\$ 16,294.36

By the chart it is determined that the cost is about \$12,800, which indicates that the bill as rendered is about \$3,500 high.

As the extensions check all right, the next step is to check the quantity blocks. By finding the intersection of the 3,200 kva demand line and line "B," read vertically downward to the energy scale, and it is found that the first quantity block should be about 224,000 kwh, instead of 352,000 as billed. As the second block represents the difference between the total consumption and the first block, it must have been calculated too small. Thus, since the quantity block which carries the higher unit rate was erroneously billed too large, and the block which carries the lower unit rate too small, it is apparent that the source of the error was in the determination of these blocks. The statement should, of course, be returned, with attention directed to this fact.

The value of the chart as a check on power bills has now been established, but this is only one of the uses to which it may be applied. Its application to the analysis of power costs as affected by the selection of the proper equipment, and the load characteristics of the equipment when in service, is equally, if not more important and valuable than for the purpose explained here. These considerations, however, will be treated in a later issue.

Galvanizing Sheets of Steel

Process by Which Galvanized Sheets Are Treated—Process of Coating Iron and Steel Sheets With Zinc—Essential Requirements of Galvanized Sheet Steel.

By C. A. DAVIS.

THE trade name "galvanizing" is given to the process of coating iron and steel with zinc. In this process, the sheets are first assembled as to gauge and widths in what are known as drafts or batches. A batch is loaded into a crate, which is made of some acid-resisting metal, and transferred to a wooden tank which contains the pickling solution and is known as the pickling tank. This pickling tank contains a solution of sulphuric acid and water of the proper strength. The action of the acid in this tank is aided by a plunger working perpendicular to the batch in the tank, which causes the pickling solution to wash evenly between the surface of the sheets.

From the time the sheets enter the pickle tank, a careful watch is kept on the same by the man in charge of the tank, called the pickler, whose duty it is to determine how long said batch shall remain in operation. This he determines by the appearance of the edges of the sheets in the batch on the up-stroke of the plunger, as the acid replacing plunger exposes the top edges about four inches.

After properly pickling, the batch is lifted from the pickle tank to one of the same construction containing water, and used solely as a rinse tank. From this tank it is again lifted to the third tank, which contains lime water. The purpose of this operation is merely to preserve the color of the sheets after pickling, so the same

can be carefully sorted into water crates, where they are submerged in a shallow tank of clear running water, after which they are returned for galvanizing.

The value of coating iron or steel with zinc, thereby protecting the material against corrosion, is dependent to a large extent on the uses to which the customer desires to put the coated material. The process of coating is as follows:

After careful inspection of the sheets in the final water crate, they are transferred to a tank containing a weak solution of muriatic acid, which serves as a final wash for impurities. From this point, the sheets are fed one at a time into the galvanizing machine. This consists of a heavy steel housing, in which rest three pairs of 8-inch rolls, namely intake, bottom and exit rolls, submerged in the molten metal or metals with which the sheets are to be coated; the surface of the molten metal being covered with a substance which serves to prevent oxidation. A man at the pot tank feeds the sheets one at a time into rubber rolls, which are mounted on top of the tank. These rubber rolls carry the sheets into the intake rolls which, with the assistance of guides, cause the sheet to pass into the bottom and likewise into the exit or finishing rolls. From the exit rolls the sheet is carried flatwise on a chain conveyor into a roller leveler which straightens or flattens the sheet. From the leveler the sheet is conveyed by chain into a cooling wheel, where it is allowed to cool slowly.

Youngstown Sheet and Tube Bulletin.

On the Manufacture of Seamless Tubes

A Series of Articles Based on the Origin of Seamless Tube Rolling in Germany, With Special Consideration of the Mannesman Pilgrim-step Rolling Mill.

Dy. DR. ING. KARL GRUBER in Rheydt.

PART IV.

IN this process a hollow bloom on a mandrel is worked between rolls so that a short part of the hollow bloom is rolled into a tube at each revolution of the rolls. We will call the end of the hollow bloom that points to the rolls, the front part, the one pointing in the opposite direction, the back part. The

importance in tube rolling, as it prevents the tube jamming on the mandrel.

For insertion into the roll of the material which is pushed back at every operation, a feeding device is provided enabling the mandrel to move to and fro in a flexible manner, while at the same time insuring

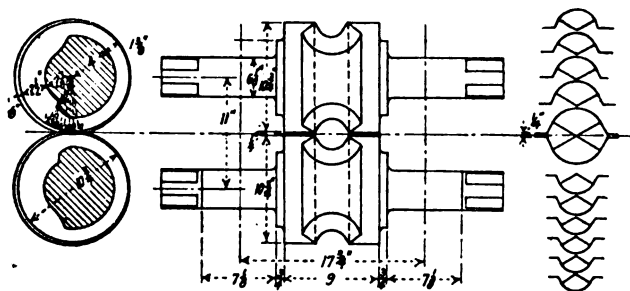


Fig. 31—Pilgrim step finishing rolls showing pass sections of the rolling cone.

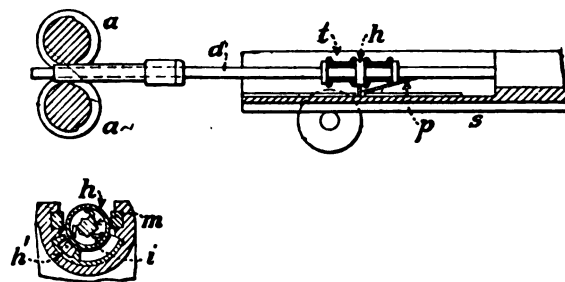


Fig. 33—Arrangement for automatically rotating the hollow ingot through 90 degrees.

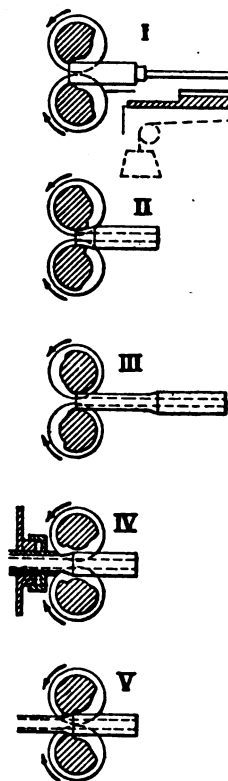


Fig. 32—Successive steps in the progress of the work on a Pilgrim rolling mill.

patent specification No. 58762, which describes the invention in detail gives various ways in which the operation may be carried out. First of all, a distinction, as to the direction in which the rolls move, is made. Experience has shown that it is desirable for the rolls to move from the front end towards the back end of the hollow bloom, i. e., the opposite of what is usual in ordinary rolling where the work is drawn into the rolls.

In the Mannesmann rolling process as practically developed, the roll is designed as shown in Fig. 31. The rolls show an increasing pass in such a way that there is an opening in one place which is somewhat larger than the external diameter of the hollow bloom. The pass tapers down gradually to the diameter of the finished tube. This point will be dealt with in detail when the different operations in the various positions of the rolls are discussed. The rolls are further provided with slightly opened sides

in accordance with patent specification No. 88638 in the way usual with rolls for round bar, and this point is of

a step by step forward movement of the mandrel together with the hollow bloom which rests on the latter. The operations (see Fig. 32) in the rolls are as follows:

In position 1 of the rolls the pass leaves a space between them into which the hollow bloom may be inserted. To limit the feed motion a stop is provided at the rear of the roll center which is so arranged that the rolls are given as much material as they are able to roll out in one revolution. In the smaller rolling mills this feed motion amounts to about 22 mm of the length of the hollow bloom. As the rolls continue to rotate in the sense of the arrow, the hollow bloom is gripped by the rolls, as shown in position

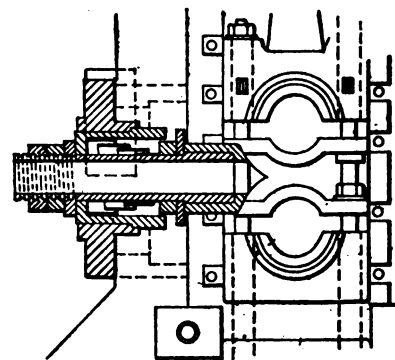


Fig. 34—Bearings for the rolls and exit guide on a small Pilgrim rolling mill.

2, because the pass begins to become narrower at this point. It is the work of the so-called roll taper by which the pass is gradually narrowed farther down, as the rotation continues, up to a point when the correct diameter of tube is reached, as shown in posi-

tion 3. The rolling process proper, therefore, takes place during rotation of the rolls from position 2 to position 3. During the two operations the bloom is pushed back together with the mandrel. The forced backward movement of both mandrel and bloom, as caused by the roll, acts against the pressure of a spring or an air cushion of the feeding device. This pressure, more especially in the beginning, is smaller than

up to a size of pass which will admit even the external diameter of the hollow bloom.

Position 5 is the position immediately preceding position 1, and from this point the cycle is repeated.

Mention has to be made of the important fact that the hollow bloom is rotated through 90 degrees at each revolution of the rolls, thus shifting the worked surface of the hollow bloom after each revolution of the

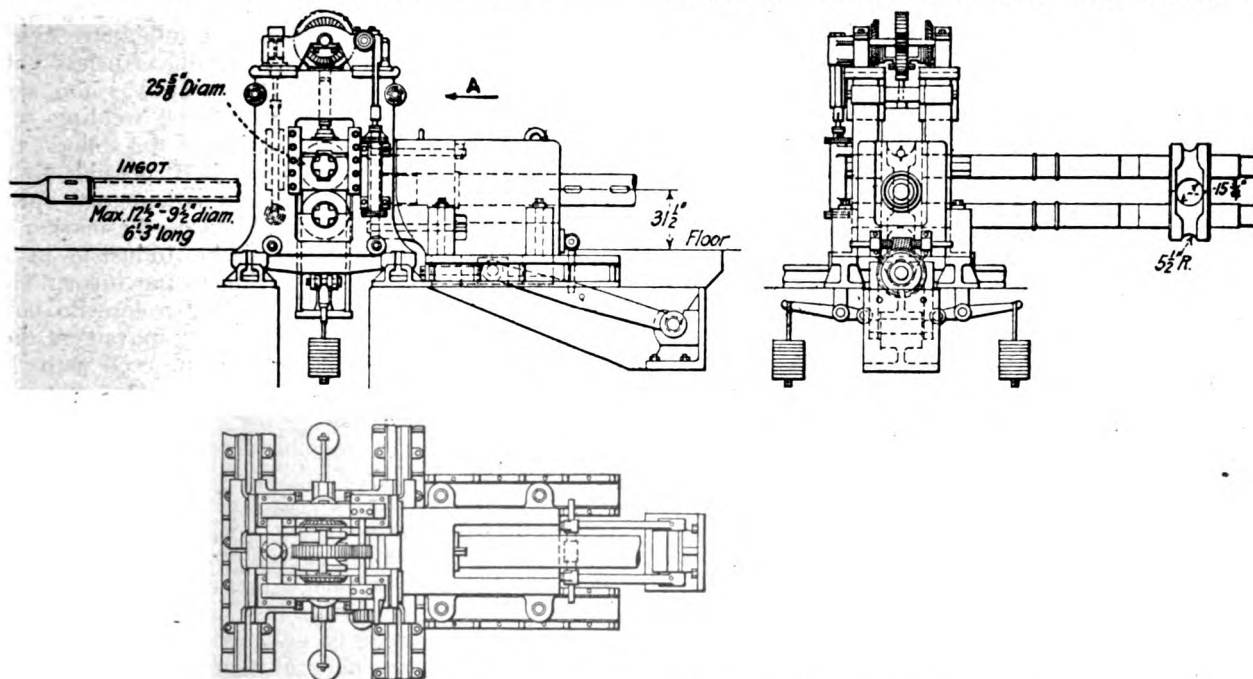


Fig. 37—Elevations and plan of a 25-inch Pilgrim step rolling mill.

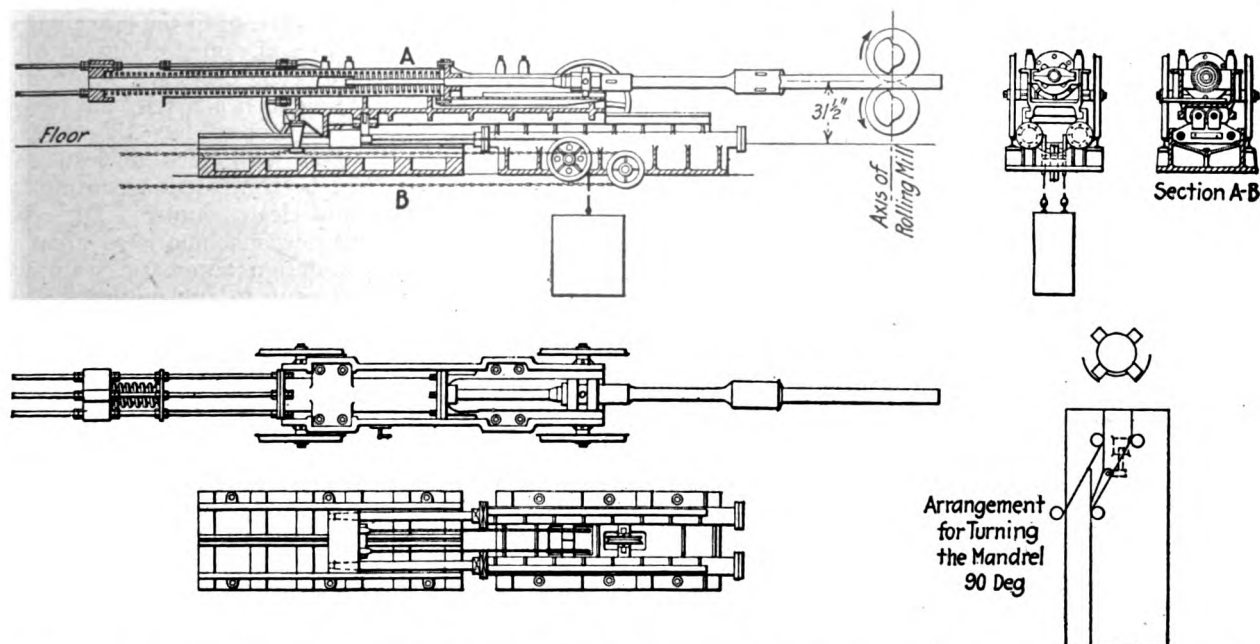


Fig. 38—Plan of the carriage on which the ram works back and forth in feeding the hollow ingot through the rolls.

the force by which the rod is pushing back the work. But as soon as the work is released again by the roll, the hollow bloom is thrown forward again together with the mandrel rod, until stopped by the stop provided. In order to insure the tube being released by the rolls, the pass of the latter at this point, as per position 4, is increased and continues increasing

rolls by this angle. This rotary movement of the mandrel rod is also effected by means of the feeding device in this way, that, by the reciprocating movement of the mandrel, a helical movement is imparted to an extension of the mandrel rod.

Patent specification No. 155228 deals with a feeding device in which the shifting of the work is inde-

pendent of its feed, as shown in Fig. 33. The top drawing shows how the device is arranged. A ratchet wheel *m* is mounted on the mandrel rod *d*. The sleeve *h* enclosing the ratchet wheel, and the pawls *i* (see cross section) are moving in unison with the slide *t*, which is connected to the mandrel *d*, the sleeve engaging in the helical groove *p* of the slide by a stud *h'*. This helical groove *p* has rectilinear shape at the end farthest from the rolling mill, causing the angular shifting of the work towards the end of the forward stroke, independently of the stroke of the work itself. The device can, therefore, be used to advantage in rolling tubes on the Perrins process (Auspilgern) in such cases when the tubes on account of their cross section can only be rotated through a certain angle in order to insure proper insertion into the rolls.

The slide is connected to springs in the usual fashion, which are compressed when the mandrel rod is pushed to the right, and feed forward the work as soon as it is released by the rolls.

When the mandrel *d* slides to the right as the rolling proceeds, the pawls of the rotating sleeve glide over the teeth of the ratchet wheels. On the backward movement of the mandrel, however, the pawls engage with the teeth of the ratchet wheel *m*, thus coupling the rotating sleeve with mandrel rod, mandrel and work, and in this way effecting the angular shifting.

The drive of the rolls and the construction of the housings is essentially the same as in standard rolling mills. The rolls are set by hydraulic or electric power and the large rolls are hydraulically balanced. The drive of the rolls is also effected in exactly the same way as in standard rolling mills, viz., by means of a spindle box. As there are jerks at each revolution of the rolls when the latter grip the material, and owing to shocks at the stop, it is advisable to make the housing of cast steel. Besides this heavy foundations for the housing have to be provided.

In the small rolling mills the stop can be a flexible one (Fig. 34). In the larger rolling mills, i. e., those for tubes of up to 11 inches, it is of considerable bulk capable of taking the shock. Figs. 35 and 36 show the arrangement in principle of a rolling mill of this description, which is of an early design.

The feeding device, as has been mentioned before, serves the purpose of effecting the feed step by step, and of imparting the reciprocating motion to the mandrel rod and its extension, further of rotating the hollow bloom through 90 degrees for each revolution of the rolls. As shown by Fig. 36 the feed motion used to be effected by means of a weight attached to the slide. There was another chain attached to the slide which could be slackened by a special device whenever the feed of the slide was to be actuated, viz., after each revolution there was a jerky slackening, so that the weight was able to act. These constructions have been superseded by hydraulic appliances.

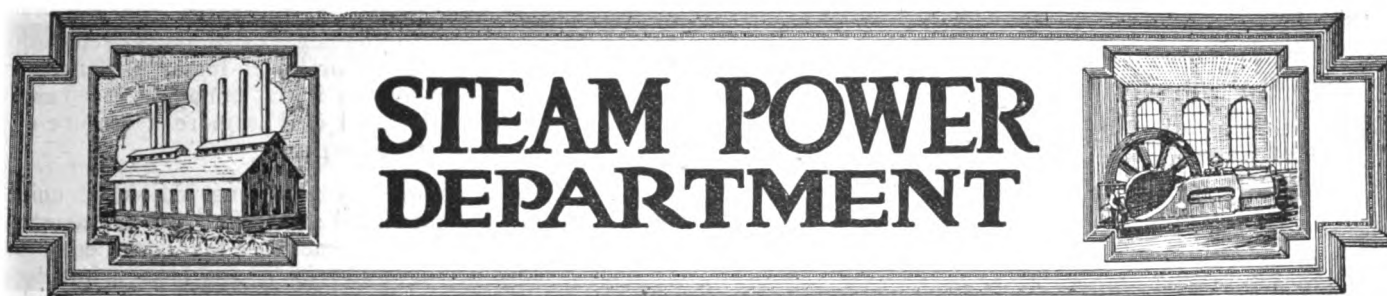
STEPPING ROLLER WELDING MACHINE.

This new electric welding machine works on the principle of resistance welding. The older types of seam welding machines used to work with uniformly turning welding rolls in such a manner that, an alternating current of low pressure (1-4 volts) and high amperage was transformed in the machine in passing from one roller to the other through the path to be welded. The material to be welded was inserted between the two rollers. The

resistance which is offered to the passage of the current at the surface of the contact of the two pieces of material to be welded together, converts the electric current into heat. The material is brought up to welding temperature and is joined together by the pressure of the rollers. By the uniform rotation of the roller the seam passing between the two rollers is welded together in one uninterrupted operation. The working speed is comparatively high amounting to $1\frac{1}{4}$ to $1\frac{3}{4}$ inches per second with sheet metal of about half a millimetre thickness. This apparently rapid process has nevertheless not been introduced to any great extent. It was too sensitive even against slight impurities of the welding surfaces and small obstacles in the rotation of the rollers, and for this reason it has in fact never been possible to assure with this process a permanently satisfactory operation. The stepping rollers process placed on the market by the Gesellschaft fuer elektrotechnische Industrie in Berlin has remedied the faults adhering to the former method. With this new process the welding rollers do not turn uniformly, but after a partial turning movement they are arrested for a moment in order to proceed with another partial turning movement. Such partial turning movements (steps) are made by the roller to the amount of 10-800 per minute, varying according to the thickness of the material to be welded. At every partial rotation a distance of from $1/16$ to $1/2$ -inch is covered by the roller, this distance varying with the thickness of the material. The welding current is coupled to the movement of the roller in such a manner that at the moment when the roller comes to rest, after having completed one step, the current is switched-on. The part of the material below the roller at that time is heated up to welding temperature and is welded by the pressure resting upon it. Immediately afterwards, the current is interrupted for a short period, the roller will keep up its pressure upon the welded part, until the latter has cooled down under this pressure and under exclusion of air to such an extent that sufficient strength is obtained to prevent the material being torn apart by any tension in the material. This new process has shown excellent results; even sheet metal with very unclean surfaces covered with scale has been welded according to this process in a faultless and clean manner. The reliability of the operation of this new machine is so great that it has become possible to design automatic seam welding machines on this principle up to any output. The wear of the electrodes which was very considerable with the older process is very small with the stepping roller; even if the sheets are covered with scales the electrodes remain perfectly clean.

SHEET METAL CONTRACTORS.

At the closing session of the seventeenth annual convention of the National Association of Sheet Metal Contractors held at the Fort Pitt Hotel, Pittsburgh, June 17, Arthur P. Lamneck, of the W. E. Lamneck Co., Columbus, O., was elected president. Indianapolis was selected as the convention city for 1922 and the trustees of the organization were authorized to invest \$5000 in government securities. Other officers elected are Frank Higgins, St. Louis, John A. Pierpont, Washington, George P. Werner, Galveston, Texas, and D. M. Haynes, Chicago, vice presidents; Edwin L. Seabrook, 261 South Fourth street, Philadelphia, was re-elected secretary and Julius Gerock, St. Louis, treasurer. W. A. Fingle, Baltimore, Frank Hiller, Cleveland, and R. E. Pauley, Mason City, Ia., were elected trustees.



Modern Steel Works Power Plant

In These Days When Economical Production Is Such a Main Issue In Manufacture of Steel, Power Plants Offer Such Possibilities of Saving That They Must Be Carefully Considered.

By W. N. FLANNIGAN,*

Steam Engineer, Ohio Works, Carnegie Steel Company.

PART II.

IT has often been suggested that the future utilization of coal for power will consist entirely of the manufacturing of coke in by-product ovens, the gas being used in engines or as domestic fuel and the coke being burned under boilers, full value of all the by-products being realized. This scheme is entirely logical, but at the present price of coal and demand for by-products it is not as yet attractive to power plant owners in this country, whether steelworks or public service corporations, on account of the tremendous outlay involved. Coke ovens are used only where there is a direct demand for coke or gas.

Theoretically the next most nearly ideal way is to burn the coal in powdered form. With this system, cheaper buildings, excellent control, perfect mixing, and elimination of ash and excess air losses are obtainable, as well as extremely high efficiencies by the use of air heaters which are considerably less expensive than economizers. However, due to operating difficulties encountered, these advantages are not being fully attained in boiler practice. When coal is burned with the theoretical amount of air, a very high flame temperature is produced, which is hard on brickwork and which liquefies the ash produced. To eliminate brickwork trouble, and also the liquid ash, which in earlier installations coated the tubes, large quantities of excess air were used which did away with some of the operating trouble, but also with one of the advantages, namely, increased efficiency due to the elimination of excess air loss, which amounts to from 5 to 10 per cent in an average stoker installation. No air heaters have been installed, which means another advantage lost.

Combustion chambers have been made large which, while it makes combustion complete and helps to deposit ash before the gases strike the tubes, increases the radiation loss and the space required. Such large combustion chambers have not been found necessary in some heating furnaces. For instance, in heating furnaces 10 pounds of coal per hour are being completely burned per cu. ft. of combustion chamber. In other words in heating furnaces an equivalent of $1/3$ of a cu. ft. of combustion

chamber per boiler hp developed is being used while 1 to 2 cu. ft. are used in boiler installations, both with stokers and with pulverized coal. Part of this rapid rate of combustion is accounted for by the fact that the flame is surrounded completely by either hot walls or hot steel, while in a boiler part of the combustion chamber is usually exposed to cold tubes. However, the greater part of the credit is due to good mixing, uniform feeding, and preheated air. Good mixing is dependent upon two factors; sufficient velocity to cause turbulent flow, and fine enough subdivision of the coal so that intimate contact with the air is assured.

The ideal and readily attainable installation will consist of a combustion chamber not any larger than for stoker practice, the burners being pointed downward allowing the flame and gases to reverse through 180 degrees before striking the tubes. The burner should be so designed that velocities above the critical will be obtained, which will give good mixing and perfect combustion with practically no excess air. The boiler should be equipped with integral air heater at the stack using the heat in the waste gases. The high flame temperature will slag a large part of the ash, which will be dropped into the bottom of the combustion chamber from which it can be run out in liquid form. The balance of the ash will pass through the boiler and out of the stack or can be removed from soot pockets in the setting in powdered form. The combustion chamber walls can be protected by passing the air from the air heater through them.

The present disadvantages of pulverized coal are:

1. The initial expense of the pulverizing plant required.
2. The labor necessary to safely operate the pulverized coal installation is as great as for stokers unless the installation is very large.
3. Danger of explosion or spontaneous combustion.
4. Pulverized coal bins are required at the furnaces or boilers.
5. Feeders and fans require power same as stokers.
6. Present feeders do not proportion correctly, i. e., for a given speed the feed varies due to different density, or aeration, and to varying moisture and fineness of coal.

*Paper delivered before American Iron and Steel Institute, May 28, 1921.

7. High cost of pulverizing.
8. Coke breeze cannot be pulverized economically on account of its abrasive nature.

None of the above difficulties are insurmountable, in fact most of them will be eliminated by apparatus just now emerging from the experimental stage.

Disadvantages of initial outlay and labor are more than compensated for by the higher efficiencies obtainable if pulverized coal is properly burned. The cost of pulverizing is being decreased due to improvements in pulverizers.

Much of the danger and all bins at the furnaces can be eliminated by circulating the coal in a solid stream through standard steel pipe by means of a pump and taking off what is needed by means of feeders, as the pipe passes the boiler or furnace. This eliminates expensive and space occupying bins and all danger of dust explosions or spontaneous combustion in the boiler house. This system has just been devised and developed and has, therefore, not been used in power plants, although it is readily adaptable. Since it furnishes a means of eliminating bins and danger it is only a matter of time until it will be found in use in power plants.

Danger in the pulverizing plant can be eliminated by proper dryer operation, by elimination of air flotation in the shortest possible space, and by a spare pulverizer in connection with the above mentioned feeding system which will eliminate the necessity of a large pulverized coal storage.

The latest feeders and burners developed agitate the coal just above the feeder proper, so that the coal always reaches the feeder or measuring device in the same stage of aeration, or fluffing, and with the effect of packing or caking eliminated. A feeder of the above type including the fan takes less power than a stoker and its forced draft fan, and perfect regulation and combustion can be secured by proper burners, which should be more than a couple of pipe fittings, as is usually found. Proper attention to mixing and to gas velocities has amply repaid the efforts in burning gas, and the same holds true of coal burners.

In addition to the high efficiency possible there is also a flexibility and ability to meet peaks that can only be obtained otherwise with a gas or liquid fuel. The standby losses are very small as banked fires are not necessary and the boiler can be entirely closed up when not required, and kept hot for long periods. Low-grade fuels, which would cause trouble on stokers or with hand firing, can be burned with little difficulty in the pulverized form, as high sulphur, sticky or excessive amounts of ash can be disposed of in liquid form. The only limit is when coal contains so little volatile matter and so much ash or foreign matter as to render ignition difficult or impossible.

In the case of boilers fired with blast furnace gas pulverized coal furnishes an excellent fuel for standby service when the gas is off, since it can be fired in the same boilers as gas, and in the same manner; no banked fires are needed, no grates or stokers need be protected; and no time or labor is lost in starting up the coal if the gas supply is shut off suddenly.

The fact that stoker firing has made so much progress in power plants and pulverized coal so little is due, in addition to being unadapted to coke breeze, to slow

development of pulverized coal apparatus, and not to a lack of realization of the advantages of pulverized coal. Apparatus that is adapted for boiler house use and requiring not too expensive an initial outlay is just being developed so that pulverized coal is more a feature of future than of present boiler plants.

Small pulverizers directly supplying individual units were tried out and discarded soon after pulverized coal began to be used. These machines take crushed coal directly, without drying, pulverize it, and blow it into the furnace mixed with at least part of the air for combustion. Poor regulation both of air supply and fineness, inability to pulverize finely, excessive repairs to high speed machinery, in addition to poor design and improper installation caused the abandonment of this scheme by many plants, including cement mills. Lately, however, this system has again found champions and is being pushed by at least two concerns, while some experimentation is being done by individual plants, including one steel works.

The advantages of such a system are very apparent, namely, elimination of handling and storage of pulverized coal, applicability to any plant regardless of size, system can be readily expanded, separate buildings not required, elimination of dryers, and elimination of most of the danger. However, up to the present time the advantages have been overbalanced by the disadvantages stated before, namely, poor regulation of air, lack of fineness, excessive repairs and the necessity of coal bunkers with coal handling machinery at each unit or group of units. There is also the possibility of burning back through the pipe to the pulverizer on shutting down.

Boiler Control.

Until the last few years conditions were tolerated in the boiler room which were eliminated in the engine room a century ago. The first steam engine had no automatic valve gear for feeding steam to the cylinders, but had a boy to operate the valves at each stroke. The engine had no governor, but on account of close attendance, slow speed and the fact that it did not have to operate in parallel with other engines, the governor was not as necessary as it is today. Imagine the engineer of today throwing the valves of a high speed engine by hand and also trying to keep the engine at a constant speed and in parallel with other units under a varying load. The above is hard to imagine now, but it is closely analogous to the boiler operation in many plants today and was the condition in all boiler plants a few years ago. The fireman and watertender had to feed coal by hand supposedly in proportion to a load of which they had no indication, they had to try and keep the boiler doing about the same as other boilers, but they had only a vague idea of what the other boilers were doing. They had to try and keep the steam pressure constant, but until the pressure had either dropped below or risen above normal and was indicated by a gauge, if they happened to look at it, they did not know whether more or less fire was needed. Fortunately, the boiler had no fly-wheel to burst and the safety valves usually took care of excess pressure, while the engine governor and valve gear took care of varying steam pressure, and economy suffered.

(To be continued)

Powdered Coal as Fuel for Boilers

A Complete Review of the Application of Powdered Coal As a Fuel In The German Steel Industry.

By DIPL. ING. F. SCHULTE.*

THE first plants with powdered coal installations at the Industry Exposition at Berlin, 1906, caused considerable comment. That the expectations, the fulfillment of which had been hoped for, were not realized at the beginning, was partly due to the then undeveloped means of grinding and crushing, partly to the difficulty of obtaining highly refractory material and, finally, to the development of mechanical stokers, which forced powdered coal installations to the rear. It is mainly the cement industry, which, disregarding the many failures, has developed powdered coal furnaces to such an extent that, today, they can be used with advantage in other industries. It must, however, be kept in mind, that the cement industry offered very favorable conditions. In the revolving kiln very high temperatures are required for sintering the cement, which high temperatures can easily be obtained with powdered coal. The removal of ashes and slag can be done without difficulty and the heat requirements are uniform. The combustion chamber is slanted downward, there are no large cooling surfaces and the refractory material is exposed to less strains and harder wear than in other types of furnace. But, nevertheless, it took a large amount of work and money, to overcome the difficulties, which originated in the incomplete combustion of too coarse fuel.

In a powdered coal furnace, the fuel, as the name implies, is introduced into the combustion chamber in the form of dust. Powdering is done in three operations, namely: preliminary crushing, drying and grinding.

Coal pieces larger than one inch must be crushed, which is done in crushers, built similar to those used for crushing hard material. Such a crusher can handle between 8 and 25 tons per hour, requiring approximately from .5 to 1.5 kwh per ton.

Before the crushed coal enters the dryer it runs through a magnetic separator, in order to free it from iron particles. The dryers are mostly direct fired drums, which, for the purpose of facilitating the movement of the coal, are slanted and built in such a way that they can be revolved. With the simplest design the furnace is arranged under the front half of the drum. The gases of combustion first play around the outside of the dryer, then enter the inside and come in direct contact with the coal to be dried. After being separated from the suspended coal dust, they

are carried away by the stack. A design which differs somewhat from the one just described, has been developed by the "Gruson" works at Magdeburg and is shown in Fig. 1. The coal to be dried travels through an annular drum, whereas the gases of combustion first heat the outside of the drum and then pass out through the inner drum.

Dryers are mostly hand-fired; large installations, however, may be fired with powdered coal. The coal in those drums, which permit a direct contact of the coal with the gases of combustion, should never have a higher temperature than 250 degrees F., otherwise the coal will be gasified and deprived of its most valuable constituents. The regulation of the temperature is done by admitting outside air, and this is the reason that an installation of this type works with a

large excess of air. The efficiency of the fuel is, therefore, very low and will hardly be more than 25 or 30 per cent.

On account of these conditions and due to the necessity of drying the coal dust to .5 or 1 per cent moisture, the plant must be under careful surveillance, otherwise losses will occur by driving off part of the volatile matter. According to the efficiency given above, a coal consumption of 3 per cent is required for every 10 per cent of moisture contained in a coal of 12,600 Btu. Brown coal can only be dried to the moisture contents of briquets (16 to 18 per cent), on account of the danger of explosion. The power necessary to operate a drying installation amounts to about 1 kwh for every ton of dried coal.

The grinders are either of the slow revolving or of the quick running type. The first kind is especially highly developed in Germany and includes ball mills and "tube" mills. The short ball mills with their large diameter are not very well adapted for coal grinding; better are the tube mills, which have their name from their long tubular shape. In the general design they mostly consist of a rougher, in which the coal is ground by means of steel balls, and of a finisher, which contains pieces of flint. (Fig. 2.) The coal enters the first compartment with nut-size and is ground there to grit, and in the second compartment to the required powder. Powdering is done by the action of the falling stones and balls. The fineness of the dust is determined by passing it through a sieve of known mesh. As a general rule it can be said that the coal is fine enough, when 90 to 95 per cent go through a sieve with 180 mesh.

The present article is believed to be of interest to the American fuel engineer, because it illustrates German practice and ideas in regard to the application of powdered coal as fuel under boilers. While in the United States powdered coal has, to a large extent, been used as fuel in industrial plants and mainly in different kinds of metallurgical furnaces, the development of coal dust installations in Germany was slow and its use was more or less restricted to a certain type of boilers. The reasons for these conditions are explained in this article.

From "Glueckauf," April 30, 1921.

The slow working mills are high in first cost and need considerable power (30 to 60 kwh per ton of dust according to the fineness of grinding). But they are, on the other hand, very reliable; they do not require large repairing and they furnish a dust of a high fineness. The manufacturers of this type expect to be able to reduce the power requirements considerably. If the material, entering the grinder, is of grit or still finer size, the front part of the tube mills with the steel balls can be dispensed with, which will reduce first cost and operating cost.

Of the quick running mills, which are chiefly developed in America, a large number of different types are on the market. The widest distribution have the Aero-mills with pestles which are attached loosely to a cross and which move in the stationary drum; the Raymond mill with short rollers suspended like pendulums; the three-roller mill with three rollers revolving in a movable drum; and the Roulette or Fuller

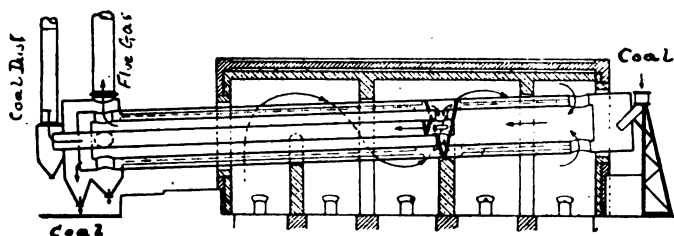


Fig. 1.

mill with revolving balls. In the last type and in the two first-named types the coal dust is ground between the grinding bodies and the shell of the drum, against which the grinders are pressed by the action of the centrifugal force. In the three-roller mill the rolls are pressed down by means of springs.

The quick runners are much less expensive than the slow working types; they, furthermore, require less space and power. According to American data, 10 to 30 kwh are necessary to grind one ton of coal dust. Reliable test data are not yet at hand in Germany. It seems, however, that the Aero mill does not come up to requirements in regard to the fineness of the coal dust. As disadvantages of the quick operating mills must be mentioned much larger operating and maintenance cost and the impossibility of grinding the coal fine enough.

Coke and anthracite are the kinds of coal which are hardest to grind. The easiest to grind is bituminous coal, somewhat less easy is gas coal. It is a known fact that bituminous coal disintegrates readily into dust, whereas gas coal breaks, when ground, first into splinters. It is, therefore, not right to say, that a coal can be ground the easier, the higher its content of volatile matter. The easiest grinding can be done with a coal with about 20 or 30 per cent of gas-content. Dry brown coal can also be ground without difficulties, as can the semi-coke or carbo-coal, obtained at low temperature coking processes. It has been proven by tests that this carbo-coal can be easier ground than the coal out of which it is made. The selection of the type of mill to be used should be decided upon from case to case, under consideration of the combustion conditions mentioned below.

Tube mills are very expensive and their installation can only be considered for very large plants, where there is the only possibility of their efficient operation.

A coal drying and grinding plant, as designed by the Polysius Company, is shown in Fig. 3. The area covered by this installation is small, because the different apparatus has been located in different stories.

The separating of the coal powder is either done with sieves or with the aid of air. Sieve-operating is generally applied for the slow going tube mills, whereas, for the quick running types air-separating is used. Sieve-separating is more satisfactory, but it is subjected to heavy wear and tear and it requires very dry coal, because otherwise the sieves will be clogged up in a short time. Air-separating, on the other hand, is simple and can take care of wet coal.

The transportation of the coal dust from the mill to the furnace can be done in three ways, i. e., either by a screw conveyor, or by compressed air or by blowers. Transportation by means of screw conveyors is good and cheap, but it is limited to horizontal distances of not more than 200 feet. All joints

the conveyor must be made air-tight, in order to prevent the entrance of moisture from the outside air whenever the mill is not working. For the transportation by means of dry air, a pressure of about 30 pounds is sufficient; it can be applied for distances of between 1,600 and 1,700 feet. Transportation by means of blowers, finally, is done with approximately atmospheric pressure. The two last named means of transporting are independent of a change in the direction of the flow, whereas the first named type is only adapted for short, straight distances. The air required is used for combustion and, in this case, it amounts to about 25 to 40 per cent of the total quantity of air required. Transportation by means of air needs about ten times as much power as transportation by means of a screw conveyor.

When air is used as the transporting medium, the coal dust is collected in a bin and conveyed from there to the burner by special appliances. Care must be taken that, with this kind of apparatus, a good

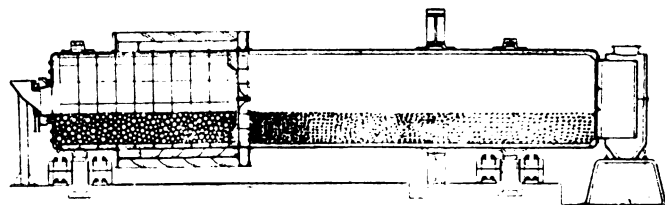


Fig. 2.

regulation within wide limits of the fuel as well as of the air is possible. Feeding of the burner is mostly done by means of a small screw conveyor. (See Fig. 4.)

The coal dust must be fed into the burner uniformly and must be prevented from sticking in the storage bin. To prevent this trouble, the bins are sometimes supplied with agitators. If the powdered coal is burned immediately or shortly after grinding, that means in a warm state, transporting to the burners can be done without any difficulties, because warm coal dust flows like water, whereas cold coal dust often forms a solid mass, which can be cut with a knife.

The burner should be as simple as possible, because complicated types have not given satisfactory results. The burner not only serves for feeding the fuel into the combustion chamber, but also for mixing

the powdered coal with the air necessary for combustion. The latter may be introduced either at the circumference of the burner or at its center. In both cases the mixing of the coal dust and the air must be complete before they enter the furnace. The combustion of coal dust requires only a very short time, in fact, it is just like an explosion. It can, however, be assumed, that everything which happens during the regular combustion of coal (preheating of the fuel, gasification and combustion) will also be found here, but that it will take place in a very short time.

Separate drying can be eliminated with ordinary coal, because it must be dried before grinding to .5 to 1 per cent moisture.

Of much importance is the determination of the conditions favorable or unfavorable for the combustion of powdered coal. A great advantage in every furnace is a high gas content. The combustion of the gaseous constituents of a fuel precedes that of the solid particles, and they generate, when burning, the necessary temperature and assist in obtaining a complete mixture of the coal dust and the air required for combustion. Another advantage is the possibility of obtaining a high temperature. In this respect, coal dust firing is superior to every other kind of firing. The temperature of combustion depends upon the heating value of a fuel. When comparing with gas and oil firing, it is well to use as a unit for the powdered coal the heating value of one cubic foot of the fuel-air mixture. The heating value of 1 cubic foot of the fuel, mixed with the theoretically required amount of air, is for

Blast furnace gas..	66 Btu.	Water gas	82 Btu.
Producer gas	73 Btu.	Illuminating gas ...	84 Btu.
Fuel oil	81 Btu.	Powdered coal	104 Btu.

It is assumed that the coal dust contains 10 per cent of ashes. Below can be found the theoretical flame temperatures for a fuel with from 12,600 to 14,800 Btu per pound, and for different amounts of air excess.

Air Excess Per Cent	Theoretical Flame Temperature Degrees F.
0	4080
25	3450
50	3000
100	2460
200	1650

In actual practice such high temperatures will not be met with, on account of a continuous heat loss through the furnace walls or heating surfaces. But actual temperatures of from 3,270 to 3,450 degrees F. have been observed with powdered coal. There is, of course, no brickwork which will withstand such high heats for any length of time, because a temperature of about 2,850 degrees F. must be considered as the limit for continuous operation. From this it follows, that the temperature must be lowered artificially by admission of a larger quantity of air, or that the furnace walls must be cooled by outside air to such an extent that a destruction is impossible. A direct contact between the heating surface and the flame has to be avoided, not only on account of an eventual destruction of the boiler plates or tubes, but also on account of the maintenance of the temperatures required for the combustion of carbon.

As was said before, it can be assumed, that in a coal dust flame first the gaseous constituents and then the solid particles will be consumed. The gaseous

constituents can be burned in the open and the temperature required for burning can be obtained by the flame itself, but the heat and temperature necessary for preheating and gasification of the fuel must be at hand under all circumstances. The combustion of the solid particles requires a higher temperature, which can not be obtained by the flame proper. From this it follows, that the flame must be surrounded carefully with walls built of refractory material, otherwise there would be danger of unburned particles of coke entering the boiler. A combustion of these particles is not possible any more, because on account of the small amount of excess air there will be no excess oxygen left for the combustion of these par-

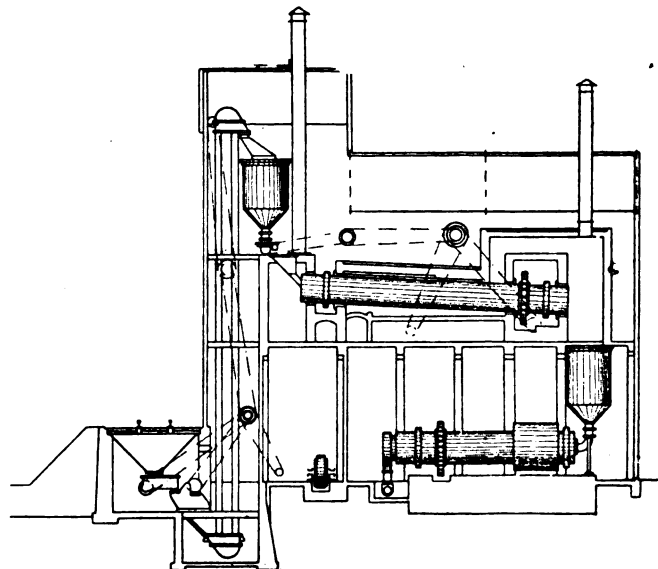


Fig. 3.

ticles. For this reason, powdered coal must be burned while in suspension.

The combustion is supported by fine grinding of the fuel. The smaller the particle, the quicker it will reach the temperature required for combustion and the larger will be the surface offered to the attacking air, thus stimulating combustion. Another aid is a complete mixture of fuel and air, also facilitated by fine grinding, but made somewhat difficult on account of the different specific weight of coal and air, as well as on account of the large amount of air required for combustion. While low grade gases, for instance, blast furnace gas, require theoretically 1 cubic foot of air for 1 cubic foot of gas, richer gases, for instance, illuminating gas, 5 cubic feet of air per cubic foot of gas, 7,000 times the quantity of air is necessary for the combustion of powdered coal.

Experience obtained from burning gas has shown that it is difficult to mix thoroughly the richer gases with the necessary quantities of air. For this reason it is hard to burn coke oven gas satisfactorily without the use of burners which guarantee a complete mixture of gas and air. This is also the cause, that gas engines can be operated easier with lean gases than with rich ones. The mixing of the fuel and air when using powdered coal is, therefore, much more difficult than with the ordinary gaseous fuels. The best mixture would be reached when every dust particle would be surrounded by an air-globule, which would represent the theoretically required quantity of air. But such a mixture will never be found in actual

practice. Such an air-globule will very likely contain several coal dust particles, whereas its neighbor may not have any at all. A steady exchange between dust and air must therefore prevail, which can be sustained by means of artificial air currents, even after the mixture has entered the combustion chamber.

Such currents may be obtained in different ways, one among which is the forcing of the coal dust air mixture into the combustion chamber with a certain velocity. In order to prevent explosions, the velocity of the mixture leaving the burner must be larger than the explosion velocity. On the other hand, it must be kept in mind, that the entering velocity must not be too big or the flame will become too long, which would be of disadvantage for steam boilers, the length of which is small anyhow. With a blast pressure of from 2.4 to 2.8 inches wc velocities at the burner

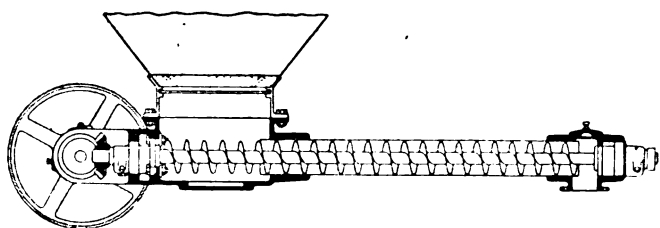


Fig. 4.

mouth, as high as from 100 to 115 feet per second will be obtained. There are also coal dust installations for boilers which work without blast pressure. In this case they are built in such a way that the coal dust is mixed with the air in the combustion chamber, thus avoiding any danger of explosion. A natural mixture can be obtained, as was said above, by the gasification of the fuel, furthermore by a sudden high heating of the air, which, at 3,200 degrees F., occupies seven times the volume than at ordinary temperature. The mixture is also assisted by a central entering of the secondary air, which penetrates, on account of the sudden expansion, the veil of coal dust which surrounds it. The same effect may be obtained by the use of several burners, pointed against each other.

A good mixture will give a short flame, because the combustion is completed in a short time. Important for good combustion is also the shape of the combustion chamber, and it seems that this point has the same or at least a similar weight for powdered coal firing as it has for chain grates, although the work done by the two kinds of firing is not exactly the same. According to experience gained in America it appears to be evident that it is not so much the flame length which counts, but the flame surface. The flame should not have an elongated, but rather a spherical shape, so that the very hot core guarantees a certain and sure burning of the coal dust, and that the radiation to the surrounding furnace space is as small as possible.

The combustion is, as is the case with every other kind of fuel, retarded by the moisture contents, which with bituminous coal, of course, may be neglected on account of the preliminary drying. Another disadvantage is due to the high percentage of ashes. The latter, in turn, is followed by a lower heat value of the fuel and, therefore, a lower temperature of combustion. The ash and slag particles, remaining after burning the combustible parts, cause very disagree-

able troubles. They sinter together and adhere to the heating surfaces; they settle as dust on every convenient place; they are carried through the stack and molest the neighborhood and form in the combustion chamber on account of the prevailing high heat the very much despised and feared liquid slag. The latter is very hard to remove and destroys the furnace walls. In the liquid state, the slag will naturally enter easily into the pores of the refractory material and into the joints of the wall, thus increasing chemical action. Another disadvantage is the high air excess, because it lowers the temperature of combustion, counterbalancing one of the main advantages of powdered coal firing. A large air excess, furthermore, increases the stack losses and decreases the efficiency. It must be said, however, that in the latter case the fuel-air mixture will be better, the possibility of complete combustion will be increased and the furnace walls will be better protected.

The preceding statements prove that there are important differences between all known modes of firing and powdered coal firing. It differs from gas firing, with which otherwise it has many points in common, that it requires a specially designed and preheated chamber of combustion, whereas gas burns right after lighting. On an ordinary hand-fired grate or with a chain grate, the volatile matter is burned above the grate and the solid matter within wide intervals on the grate. This is different with powdered coal firing, where there is really only a combustion above the grate, that is, the coal dust must be consumed as long as it is suspended.

To those points explained in the preceding paragraphs, grinding and combustion of every kind of coal must be adapted. A coal rich on volatile matter, naturally, will burn easier and will develop higher temperatures in the combustion chamber quicker than a coal containing less volatile constituents. Such a coal very likely does not require a very firm grinding and thorough mixing. Coals low in volatile matter, which, as a rule, burn slower and which reach high temperatures in the combustion chamber less quickly, must for the same reason be ground very fine, in order to obtain complete mixture. Besides, the combustion chamber in the latter case must be designed more carefully in order to maintain the temperature required for combustion. In this connection it must be remembered, that low grade fuels show the more the character of fuels low in volatile matter, the more ashes they contain (disregarding the moisture contents on account of the preliminary drying). Refuse of gas coal with 60 per cent ashes and with 30 per cent of volatile matter in the original coal, will, therefore, contain .6 x 30 or 18 per cent volatile matter. This refuse, therefore, corresponds to lean coal.

The high temperature obtainable with powdered coal acts favorably for its use under boilers. It is a well-known fact, that high efficiency and good operation of water tube boilers, fitted with traveling grates, is due mostly to high temperature of combustion caused by the radiated heat. The possibility, to expose a large part of the heating surface to the radiation from the hottest part of the grate, does not exist with powdered coal firing. Here the flame is not supposed to give up its heat directly by radiation or by convection to the heating surface, because, in this case, incomplete combustion of the coal dust would be the result. For this reason a return tubular

boiler, supplied with a powdered coal installation, will have to be bricked up over its whole length, which, in turn, will diminish the action of the most valuable heating surface to a large extent. According to the experience, collected to date, preheating will hardly be avoided with this kind of boilers. There will then be the possibility of carrying out the combustion partly in the Dutch oven and partly in the tubes. If combustion takes place in the Dutch oven, no lining is required in the fire tube. With water tube boilers, on the other hand, the combustion must take place in the Dutch oven. This disadvantage is partly offset by the heavy eddy currents, which are necessary for powdered coal firing, and which increase the possibility of making use of convection. High ash contents will make, aside from the other disadvantages shown above, part of the heating surfaces useless, because they will settle on them and will cake. These cakes must be removed from time to time, while the dust deposits must be blown out in the usual manner. The liquid slag must either be removed as such or it must be granulated before removal, which can be done by counter-currents of the cold air required for combustion.

We will not deal here with the requirements to be observed for the refractory lining of the combustion spaces, but will only mention the fact that the ashes of the coal to be used have to be analyzed chemically, because the kind of refractory lining to be applied depends to a large degree on the chemical composition of the ashes. In general it can be said, that with a basic slag no acid material should be used and vice versa.

The advantages connected with powdered coal firing are as follows: The efficiency of the boilers will be higher than that of the boilers having hand-fired grates. The air excess can be lower, which reduces the stack losses. But, as was stated before, the oxygen content of the flue gases must be higher than that obtained in coal dust fired cement kilns (.5 to 1 per cent) on account of the safety of the lining, thus requiring practically the same amount of excess air as is required with chain grates. For this reason powdered coal will probably give no higher efficiency than the latter type of grates and it very likely will, on account of the high cost of grinding, be restricted to those types of boilers, for which chain grate stokers are out of the question, and which are the return tubular boilers, used extensively in Germany.

The readiness for operation is said to be larger with powdered coal installations than with any other type of firing. If the temperature required for the combustion of the fuels is once reached, a quick increase of the flame temperature is possible, but care must be taken that this temperature does not get so high as to destroy the lining. Readiness for operation is, furthermore, depending upon the moisture contents, upon the size of the walls, their tightness, upon the length of the shut-downs and upon the kind of fuel. A big advantage, which will be found with every powdered coal fire, is the completely smokeless combustion. Worth mentioning are also the small draft losses, because there is no resistance through the grate and the quantity of waste gases is small on account of the small air excess. This condition may be of large importance with heavy overloads and it may save a rebuilding of the stack. The higher temperatures will, in turn, cause heavier loads, thus either allowing the use of a smaller number of boilers, or preventing the

installation of new economizers. Such conditions will have to be considered, whenever old overloaded plants are to be changed to powdered coal firing.

A regulation of the amount of coal dust required and of the necessary quantity of air is always possible within wide limits when the installation has been designed in the right way. This regulation may vary between 0 and 15 per cent of the normal capacity. The fire can be turned out at once, which, under certain circumstances, for instance, to prevent the blowing off of the safety valves, may be very important; this blowing off causes, according to recent observations, more losses than has been generally believed. Another big advantage is due to the absence of grates and of other movable parts within the combustion chamber, because all movable parts for a powdered coal installation are located outside of the fire zone. The transportation of the fuel to the burner by means of a screw conveyor, compressed air or blower, is comparatively simple. The main advantage, however, is due to the saving of labor. Although two men are required to operate the dryers and grinders for an installation large enough to serve 20 boilers, probably one or two men are necessary to take care of the boilers proper. These two men can also easily take care of the pumps and the water gauges. The operation of the furnaces is so simple that it can be thrust into the hands of unskilled labor. This would make the operation independent of the skilled boiler operators, which would be of advantage to the mines, which always have to suffer for want of good men.

These advantages are counterbalanced by very essential disadvantages. In the first place has to be mentioned the high first cost, which, under present conditions, amounts to over \$250,000 for a tube mill with preliminary crushing and drying, having an hourly capacity of 3 tons, which would be sufficient for 10 R. T. boilers of about 325 square feet heating surface each. For a capacity of 6 tons per hour, this price would be nearly \$500,000. This sum does not include freight for the machinery, erection and buildings. The operating cost is also high. It is composed of the cost of the power required for the crusher, dryer, grinder and transmission machinery, of the fuel cost for the dryer, and of the general operating cost, and of maintenance, interest and depreciation. To this have to be added the cost for removing ashes and slag, for repairing the firebrick lining and eventually the expenses for a better and more careful water cleaning, which is necessary on account of the higher boiler capacity. These are the reasons, that, as is said in America, a powdered coal installation operates efficiently only in such a plant where the daily coal consumption is about 100 or 120 tons.

Conditions for the introduction of powdered coal firing are not unfavorable when the power plants for mines come into consideration. These are mostly plants with a daily coal consumption of around 120 tons, where there is plenty of space at hand which can be used for the coal dust machinery. There are, furthermore, all the necessary repair shops so that no difficulties will be encountered if anything gets out of order. Especially the coal in the Ruhr basin is well suited for powdered coal firing on account of its gas content. Besides, nearly all the boilers in mine power stations are return tubular boilers, for which a grate equivalent to the traveling grate has not yet been invented. For instance, in the mining district

of Dortmund, Westphalia, 68 per cent of the total number and 75 per cent of the stationary boilers are return tubular boilers. For these boilers coal dust firing will permit a much better utilization of the fuel. The main reason, however, which has the most weight in this connection, is the fact that enough coal dust is at hand at the mines, without having to resort to grinding. In some cases air separating will furnish between 50 and 60 per cent of coal dust per day, which up to the present time has been practically worthless. Part of it may be sold to foundries, part of it is used with the coking coal and gives coke of inferior grade, and some may be used with the boiler coal, decreasing the value of this coal as fuel. Where the dust is not aspirated it remains in the coal to be washed and goes with it into the washers, where it is an obstruction against washing. It finally appears further mixed with gangae, as mud in the sumps. This mud has, therefore, a much higher content of water and ashes than the dust aspirated before washing, and it is consequently a fuel of minor quality from a technical standpoint.

Experiments have shown that the dust which was aspirated in most cases has less than 1 per cent moisture, and seldom more than 1 per cent, but never more than 2 per cent. Dust with such a low moisture content can be ground without preliminary drying, thus saving at the mines the sensitive and expensive dryers. Of the aspirated dust, about 20 to 30 per cent have a fineness which permits a direct use in the burner, and the rest is in most cases fine enough that it permits the elimination of the rougher of a tube mill. This, also, means a decrease in first cost and in operating cost. Quick running mills give, under these conditions, a higher tonnage, and, with a certain definite capacity, it is possible to operate with a smaller number of mills.

Conclusion.

After a review of the development of the powdered coal firing in Germany, the installations and machinery are described which serve for drying and crushing or grinding the coal, for transporting it to the burners and the burners proper. Then follow data in connection with an efficient or inefficient use of the coal dust and data about the advantages and disadvantages connected with this type of firing. Finally the conditions are explained, which have to be considered when it is intended to install powdered coal plants at the mines.

SPEEDY ACTION URGED TO START BUSINESS AGAIN.

Speaking before the Pittsburgh Association of Purchasing Agents at the Ohio, Tuesday evening, J. A. Campbell, President of the Youngstown Sheet & Tube Co., made a straight-from-the-shoulder, shirt-sleeve talk on the difficulties of present business conditions and the necessity that something definite be done to correct the situation, if it is not to drag along from bad to worse for several years.

President Campbell said the situation would eventually right itself even though nothing were done. He declared, however, that the country could not afford to pay the price of such a solution. Radicalism, more government interference with business and possibly federal control in important lines with the inevitable attendant

ills such as were seen during the war, would be the result, he asserted.

The speaker said that he had that day wired the president opposing legislation looking to the extension of federal control and urging the president's own slogan of less government in business and more business in government. He mentioned opposition in particular to the Frelinghuysen coal stabilization bill. President Sanborn of the Purchasing Agents Association later informed the speaker and audience that his organization that day had adopted resolutions opposing the Frelinghuysen bill and communicated them to Congress.

The steel-maker mentioned the absence of foreign trade, the improbability of any substantial revival in that quarter for some time and the handicaps being imposed on American industry by competing with the low priced labor of Europe. Much could be done to ameliorate this situation, he declared, by adjustments here at home.

In this connection President Campbell insisted that lower freight rates, permitting movement of commodities over the long hauls in this country and to seaboard points for export at fair charges and the adjustments of labor rates on a relatively equitable basis throughout the country, are absolutely fundamental to any attempt at correcting existing difficulties.

The speaker mentioned recommendations that he would make in this respect to Congress. These included repeal of the Adamson law, which he branded legislation to increase wages rather than to adjust working conditions; what amounts to discontinuation of the railroad labor board; restoration to the railroads of wage control, settlement between the government and railroads permitting repayment by the latter of advances made for improvements during the war in 15 annual installments and payment to the carriers of amounts due them from the government.

Much condemnation was voiced at the present impossible tripartite control of the roads by the managers, the interstate commerce commission and the railroad labor board. This situation was declared impossible owing to conflicts of authority and lack of coordination. If there must be a labor board let it be one representing the public only, it was urged.

Something must be done for the railroads and that quickly or important systems will be in the hands of receivers soon, it was declared. Nothing but speedy legislation unshackling the roads will help. We can't wait with men walking the streets and another winter coming on, said the speaker.

The necessity of helping the farmer get his crops to market at a fair price so that he would be able to make his influence felt again as a buyer, was emphasized. Excessive freight rates have virtually cut the farmer from his markets or left him so little when he does ship that his purchasing power is practically destroyed. This was declared to be one of the most damaging features of the domestic situation.

President Campbell said he was opposed to a high tariff, but that people should be willing to pay some tariff for the privilege of living in a country such as this. He said labor is working in Europe for the equivalent of 10 or 12 cents an hour in U. S. money and that there is little spread between common and skilled labor rates there.

The fact that Germany is underselling U. S. in Japanese markets \$20.00 a ton of steel was mentioned.

Pulverized Firing in Steam Generation

General Discussion of the Use of Pulverized Coal — A Typical Layout of a Successfully Operated Plant.

By F. J. CROLIUS,

Steam Engineer, Carnegie Steel Company, Munhall, Pa.

Philosophy of the Subject—Hazards.

PROBABLY the first thought that comes to the average mind when pulverized coal is mentioned, is its danger; and not without reason, for finely powdered coal under certain conditions is a very dangerous plaything—but only under certain conditions.

This fact is well known, but until recent years not well understood.

The conditions under which it is dangerous, are diffusion in atmosphere unmixed with a non-combustible solid, or confined, as in a chamber or mine, mixed with an inflammable gas like methane, and under these conditions brought under the influence of ignition.

In cement plants, or mining concentrating plants, we find the conditions of non-combustible present—there the hazard is very low.

At the Universal Portland Cement plant, operating 28 pulverizers over a period of 12 years, averaging close to a ton of coal per hour, they actually tried to create a condition of explosion, but were never able to do so. These were aero pulverizers, direct fired on undried coal.

Stored coal will spontaneously burn and coke, but this is not necessarily a danger.

Conditions under which finely powdered coal is not dangerous is where it is not stored in bins, nor allowed to accumulate in inaccessible nooks, or where it is burned immediately as pulverized, without allowing any chance of leaking out into a dust-cloud formation.

Where distribution is systematized, if the complete system is properly designed and adequately built and sealed, and the flow of coal through the system is continued uninterruptedly, there need be but little danger.

Where coal has to be dried before pulverizing, and most distributing systems require that the coal be dried, the drier itself offers the ignition point, where

danger exists. Great care must be observed at this point in order to reduce the hazard to a minimum.

The entire safety of the pulverizing plant largely depends on the man tending the fire in the drier.

This entire subject of pulverized coal hazards has been carefully observed and analyzed by the Bureau of Mines; an excellent paper by Mr. L. D. Tracey of that bureau covers the finding to date so comprehensively that we can do no better than repeat his conclusions. They appear as follows:

Explosions have been more disastrous if they have happened in the buildings housing the pulverizing machinery.

Adequate ventilation is necessary to prevent the formation of dust clouds.

A mixture of .032 of an ounce of coal dust (just covers a silver quarter) per cubic foot may cause an explosion if ignited.

A definite amount of incombustible mixed with the coal dust will render it non-explosive — this depends entirely upon the ratio of volatile to total combustible. Naturally high ash coals and low volatile coals are lowest in the scale of explosibility.

Powdered coal bins should never be located near or above an active furnace.

Spontaneous combustion at or near the driers have

been a frequent cause of fire.

"The rate of absorption of oxygen increases so greatly with the rise of temperature that the warming of coal by a steam pipe or boiler may enormously shorten the time necessary for spontaneous combustion."

Above 150 degrees F. the rate of oxidization is very rapid. This should be the maximum temperature of any coal delivered to a storage bin.

Investigation has shown these temperatures frequently exceeded.

Electric flashes will ignite a dust cloud and all switches should be safely outside the danger zones. The dangers from motors are so great that the

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 - b. Successes and reasons for success.
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Auspices Combustion Engineering Section, A. I. & S. E. E.
Presented at Pittsburgh Monthly Meeting, May 14, 1921.

Bureau of Mines has classified motors into two classes—permissible and others.

Even the breaking of an incandescent lamp bulb may ignite a dust cloud.

There is, however, a solution to this apparent combination of hazards, as can be seen from this summary of conditions. It is merely a question of recognizing the fact that a hazard exists and preparing accordingly.

The psychology of the matter is the fear, or question of fear, that has surrounded pulverizing in general. Undoubtedly, this factor has retarded the development of pulverized firing as a power fuel, because, to many, this has seemed like a compounding of two dangerous practices. High pressure boiler operation has always been considered hazardous. Let us see what the facts are.

Safety.

Under the general head of safety we can investigate accidents in boiler houses, we can subdivide these accidents into classes and proportion the classes.

Investigation along these lines will show, if we take the largest industrial corporation as a criterion, that hazards, attendant upon boiler operation, are absolutely the lowest in actual percentage of all mill accidents.

As a matter of fact, the majority of accidents about boiler operations are minor cases. A small proportion only being lost-time cases. And these cases the application of pulverized firing will very greatly reduce.

The actual percentage of accidents occurring in the boiler houses of one of the largest plants in the Steel Corporation, over a period of ten years, was only one-hundredth of one per cent of all mill accidents—while for the entire corporation the percentage stood at eight-hundredths of one per cent (.08%).

Surely not very dangerous practice.

While there have been a number of accidents, some serious, occurring in and about the pulverizing plants themselves, I have never heard of a serious accident in a boiler house where pulverized coal is burned as a fuel.

Steps in the Development of Pulverized Operation. Failures and Causes for Failures.

In 1846 patents were issued in England for a pulverizer and a pulverizing combination under boilers, which if installed according to the patent specifications under a modern boiler would have given successful results. But the boiler was of the 1846 vintage and the laws of combustion were then not so well developed.

From that time forward, frequent attempts have persisted, special boilers, like Bettington, have been designed—but the many attempts under boilers were failures.

The probable reason for most of the failures is not difficult to trace; it was the size of the boiler and the character of the setting plus a lack of knowledge of combustion.

If we merely glance back twenty years, we will find a 250-hp water-tube boiler considered mammoth. And if we attempt to measure the size of the combustion chamber we will find a micrometer necessary—there was no combustion chamber as we now understand one. Today we design a combustion chamber, and then build a boiler around it.

The operating conditions which resulted in failure were definitely—slagging upon tubes, destruction of brickwork, cost of maintenance, and expense of installation.

Early experiments were naturally applied to the smallest unit available, as the experimental cost would then be reduced. But the small boiler and setting was just the unit which should have been carefully avoided. I have no hesitation in saying that if the early experimenters had started with the new Ford boilers, with their adequate combustion chambers, they would have been rewarded with success.

Proof of this exists in several directions; cement kilns with their enormous chambers, enormous in relation to fuel requirements, were successful from the start.

Open-hearth furnaces, although having a smaller proportionate chamber, experience no difficulty from a combustion standpoint. Their troubles lie elsewhere.

Continuous heating furnaces show beautiful combustion. And so on.

Success and Reason for Success.

But all of that is of the past; pulverized firing in the future should record nothing but success, at least there is no reason why it should not.

It is no longer an experiment—a number of men, by their untiring energy, patience and resource have developed pulverized firing into a science. As engineers, we owe them a tribute; as operating superintendents, we owe them a vote of thanks; as executives, we can afford to reward them with an annual bonus.

John Muhlfield you have all listened to; to him and his associates, Mr. Carachristi and Mr. Savage, our debt is large.

To John Anderson of Milwaukee, whose plant at Milwaukee is now the Mecca of power-plant engineers the world over.

To Mr. Turner of the Ford Company, and your own Mr. Ladd, who have had the courage and resource to visualize their imagination into the present wonderful Rouge River installation.

These and many others have laid the secure foundations upon which an ideal edifice is arising and will continue to rise.

The Locomotive Pulverized Equipment Company, the Combustion Engineering Corporation, The Fuller-Lehigh Company, The Bonnot Company, The Quigley Company and the Aero Pulverizer Company are a few of the pioneers who have met the problems, and have "licked them," to use that popular expression.

A few moments ago we spoke of failures; failures they were, but the biggest failure was small in comparison with the present success.

A visit to Milwaukee will silence the worst skeptics. It is unnecessary to discuss in detail that remarkable development—it is too well known to require comment—sufficient that a kilowatt is there produced on 19,000 Btu.—the lowest recorded from any power plant.

Those of you who are familiar only with steam generation from blast furnace gas, aided and abetted by occasional hand-fired run-of-mine coal, should spend a day at River Rouge. You will awake to find yourselves in another world.

Visit the Bethlehem Steel Company at Lebanon; the M., K. & T. R. R. at Parsons, Kansas; the Puget Sound T. L. & Power Co. at Seattle; United Verde Ext. Mining in Arizona, Nevada Consolidated Mining in Nevada; A. Hanna Mining Company at Lytle, Penna., and the Allegheny Steel Company at Brackenridge, Pa.; the Erie City Iron Works, or at Homestead, there you will find steam being generated with a variety of boiler types.

Edgemore, Ladd, O'Brien, B. & W., Stirling, Heine, Rust, Wickes, Erie City, Cahall, and Return-tubular—in sizes of units ranging from 150 hp to 2,500 hp, burning every character of coal from Nantaimo slack of 9,300 Btu., with 28 per cent ash, anthracite slush of 13,000 Btu. with 24 per cent ash; Illinois slack with 10,000 Btu. with 14 per cent moisture to good Pittsburgh steam coal.

You will find boilers being operated at any ratings desired, at efficiencies irrespective of coal analyses, averaging about the 80 per cent mark.

It may also be of interest to mention that the General Electric Company was one of the pioneers in the field (having had in its Schenectady plant one B. & W. boiler equipped and operating for many years. They have issued test data from which successful conclusions may be drawn.

These plants are successful—and very successful.

Two Distinct Schools.

Many engineers have attacked their problem in many different ways, but the result of these various lines of attack have developed into two schools of pulverized operation.

- a. The indirect or concentrated preparation plant.
- b. The direct fired.

The indirect method was the logical first step in the application of pulverized fuel under boilers—it presupposes the existence of pulverizing equipment already delivering pulverized fuel for some metallurgical purpose in a plant, and the extension of this pulverized fuel to boilers, already existing.

In this method the coal is usually prepared in a central pulverizing plant, conveyed to the boiler house and distributed to the boiler furnaces.

Methods of Preparation.

Preparation involves unloading the raw coal, elevating it to bins, removing the surface moisture by heating within a revolving indirect-fired drier, elevating the dried coarse coal to the dried coal bins—pulverizing the dried coal in any of the many types of pulverizers; roller, ring-roll, ball or tube—such as Raymond, Bonnot, Fuller, Hardinge, or Kennedy; exhausting the finely powdered coal from the pulverizer into a separator, from which it is conveyed by screw or air to points of consumption. It will be noted that these enumerated activities require a definite number of motors per unit of operation, in no case less than six (6), usually more.

As mentioned, there are many kinds of mills, each with their firm adherents and also their firm antagonists; we need not enter into that discussion, the comparative data can be assembled by any engineer. Suffice to say, those mentioned are all commercial successes, they do their work, and all have their troubles.

The crux of the discussion has centered about the Method of Distribution.

Fundamentally there are three (3) methods of distribution—screw conveyor, volume air at low pressure, high pressure air.

Screw conveyors are costly to install, maintain and operate. Volume air at low pressure raises the question of a possible combustible mixture, and require much power.

High pressure air costs money to install and operate.

Holding no brief for any one of these methods, the latest development which seems to offer the approach to an ideal, is the combination of high-pressure aeration with the displacement pump developed in the Fuller-Kenyon combination. This seems to combine the elements of low cost, low power, flexibility and reliability.

Method of Firing.

Having brought the pulverized coal to the point of consumption, it is now a simple matter to fire it. You are all familiar with the various types of feeders, controllers and burners, all have been pictured, discussed and featured. All are good, but none are automatic. Most of them are based on the same principle, a small motor driven screw feed, connected under a bin and supplied with an air current.

Direct Method.

In the direct method of pulverized application to boiler firing, the pulverizer is placed directly at the boiler, the existing raw-coal handling equipment is utilized, the coal is fed to the pulverizer undried, and is exhausted directly into the boiler furnace or combustion chamber. There is no hazard from driers, no hazard from bins, back fires from momentarily unbalanced pressure; there is no storage of gun-powder, to quote Sam Wales.

Instead of a minimum of six motors being required for the operation, one motor or turbine may suffice. The power which is required to drive the exhauster fan alone in the indirect method, is almost enough to perform the entire operation alone in the direct method.

The burner and ignition problem is the same in both methods but the direct method is more susceptible of automatic control. Such is now applied. The aero pulverizer has been the unit most used in direct firing. The Hagan control has been applied to this.

Comparatively little development work along direct firing of boilers has yet been attempted. The most obvious reason, in my mind, has been the sub-conscious thought that pulverized firing was a very mysterious and difficult engineering feat—and must not be attempted without spending a fortune. It may be that suitable equipment has not been available, or the fact was not known that 95 per cent—200-mesh undried coal was not needed.

However, its manifest advantages warrant considerable development, and such development work is now in progress.

Combustion Chambers.

The most important feature and the feature upon which successful operation entirely hinges is the combustion chamber.

Here again, we find two schools.

- a. Water-cooled.
- b. Air-ventilated.

The water-cooled chamber seems to have been a development made to overcome the lack of cubical contents possible under small, badly set boilers. This is a development of the Erie City Boiler Works—where one is in operation.

Certain claims have been made for it as to capacities, and many tests have been run to verify these claims, but since the character of wall construction affects in no way the fundamental laws of combustion, which are primarily based upon temperatures, air dilution, velocities and the resultant time element, I feel that much is left to be proved. Whether or not the saving in annual repairs will repay for the large investment is a matter of determination.

The usual construction of furnace is an air-ported or ventilated structure—this is nearly universal practice.

The fuel is admitted either horizontally or vertically or at an angle.

The preference as to the method of admission depends upon local limitations entirely, combustion results are uniformly good with all, provided the operation is proportional to the capacity of the combustion chamber. There are fewer operating difficulties with vertically fired furnaces—boilers at Milwaukee kept on the line six or eight weeks.

There is still considerable practical experimental work in progress toward the development of an ideal furnace, and such research will undoubtedly continue as long as man is ambitious.

Boilers.

In the discussion of generating units, I have divided all boilers into two classes: a. small boilers; b. large boilers.

By small boilers I mean all units below 500 hp; by large boilers I mean those units above 500 hp.

This is an arbitrary and a very rough classification, but it represents generally a period in the history of water-tube development previous to (1904-1910) and from that time forward.

The general scheme of operation of small boilers was quite different from the present methods of operation of larger units.

The era of many small units, natural draft, was more or less a period of hit and miss low-rating operation, involving expensive coal handling and ash conveying, a perfect picture of unregulated, unrecorded, unanalyzed operation in the hands of a multitude of relatively low-paid practical firemen and laborers.

Efficiencies were conspicuous by their absence, and the efficiency engineer was as unwelcome as the plague.

The large boiler changed all this. Today we have, as standard practice:

- Adequate combustion chambers.
- Forced draft air supply.
- Correct feed-water regulation.
- Flexible damper and fan regulation.
- Proper conditioning of make-up water.
- Practical flow-meters for water, steam and air.
- Practical recorders for gas analyses.
- Combustion data and combustion schools, accessible to all.

In fact, a concentration of efficient operation in the hands of experts whose evident aim is the reduction

of human hand power to the very minimum.

Where formerly it required one man to produce 250 hp. today one man can produce 5,000 hp.

Where formerly the annual cost, at 50 per cent efficiency, averaged well over one hundred (\$100) dollars per hp year, today at 80 per cent efficiency that hp can be produced for \$50.

And right here pulverized firing will play its important part.

Numerically the small boiler demands attention, for more steam is still being produced in small boilers than in large boilers; expressed in round numbers, some 100,000,000 tons of coal are consumed in small low-efficiency plants, as against 75,000,000 tons in large boilers and the comparison of cost between them stands safely at a three to one ratio against the small plant.

Here, then, is the immediate field for pulverized application—for remarkable as it may seem, the actual efficiency obtainable in any type or size boiler, using any kind of coal varies but slightly; when the setting is properly proportioned.

The small boiler can be made as efficient as the large.

Costs.

This naturally depends largely upon the size of the new installation, and the choice of equipment selected to do the work. On this score, there are many opinions, with which we will take no exceptions. In general, it may be said that a complete plant, including all coal handling and pulverizing equipment, boilers, furnaces, fans, motors, etc., can be erected at about the same investment cost as the capacity stoker equipment would cost. This applies to an indirect fired plant.

The cost of re-equipping existing boiler plants can be made less on pulverized basis, and is usually more practical, as the forced air supply, incident to pulverized firing, vastly simplifies the question of a change to forced draft.

Careful analyses of many comparative operations indicate a lower cost-operation for pulverized firing than for stokers.

As these comparisons have quite largely centered about central station practice, wherein stoker practice has reached its maximum, I am rather inclined to believe that average comparisons which included stoker practice in average industrial operations, would very strongly favor the pulverized operation.

A comparison of costs covering a 20,000-hp operation appears as follows:

	A	B	C
Boilers	\$ 330,000	\$ 330,000	\$ 330,000
Settings	190,000	240,000	240,000
Stokers	190,000		
Pulverizing equipment ..		369,000	80,000
Bins	130,000	140,000	130,000
Buildings	200,000	170,000	200,000
	<u>\$1,040,000</u>	<u>\$1,249,000</u>	<u>\$ 980,000</u>
Operating cost—not including interest on investment, taxes, depreciation, etc...	\$ 55	\$ 49	\$ 48.70
	1,100,000	990,000	920,000.00

As a justification of any economic theory or suggestion it is often fruitful and interesting to cast it into perspective against the total economic background. Especially is this true of coal.

As an industry, the mining, the transportation and the consumption of coal, one of our most useful and valuable sources of natural wealth—as an industry, nothing but coal could bear the burden of inefficiency and waste which characterizes the course of this product from its origin to its destruction.

It is a major subject in itself.

Coal has aptly been called "Black Diamonds"—and the term is most appropriate—not because of the color significance, because all coals are not black—some are gray, and others brown—but rather on account of the somewhat less obvious analogy—that to the diamond itself. Diamonds are precious because they are a luxury, and they are a luxury because they are expensive; one of the vital reasons why they are expensive is because of the very small proportion actually recovered in the process of making them valuable.

It is in the relation of wastes of both diamonds and black diamonds that we find the real points of analogy.

There are approximately, as applied to our problem—

8,000,000 hp in central station power plants	20 per cent mechanical equivalent
10,000,000 hp in industrial low-efficiency plants	3 to 8 per cent mechanical equivalent
8,000,000 hp in industrial higher-efficiency plants	8 to 15 per cent mechanical equivalent

These plants consume nearly 175,000,000 tons per year, more than 25 per cent of the total coal mined in this country.

More than 120,000 men are employed in the steam plants
More than 170,000 men are employed in the mining of coal
More than 130,000 men are employed in the transportation of it

If all these plants are equipped for pulverized firing, at least it would save:

30,000,000 tons worth \$4 per ton.....	\$120,000,000
50,000 employees at \$2,000 per year...	100,000,000
200,000 empty return car miles at 10c..	20,000,000
	\$240,000,000

These figures are, of course, approximations.

The cost of equipping the average boiler will not exceed \$20 per developed hp.

$$10,000,000 \text{ hp} \times \$20 = \$200,000,000$$

In these days of extravagance and waste reductions, there is no more fertile field and none more sure of adequate returns.

Economics of the Subject.

Let us glance at the distribution of the coal mined last year in this country alone; its allocation will indicate our problem.

600,000,000 tons mined
150,000,000 tons used by railways
100,000,000 tons used by ships and exported
100,000,000 tons used in domestic homes
75,000,000 tons used in coke

425,000,000 tons

175,000,000 tons used in power plants; large and small
75,000,000 tons used in 20 per cent efficient power plants
100,000,000 tons used in 3 to 15 per cent efficient power plants

The cost of producing power in a small plant—that is:

Below 500 hp is about 4	times the cost of a 10,000 hp plant
Above 500 hp is about 3	times the cost of a 10,000 hp plant
Above 1,000 hp is about 1½	times the cost of a 10,000 hp plant

and of this total cost, items of coal and labor are a rapidly ascending curve in inverse ratio with the size of the plant.

Numerically the small, low-efficient, high-cost plants are decidedly in the majority and these should be the logical points of attack.

The general impressions have been that pulverized firing was not practical in plants below 2,000 hp. Nothing could be further from the truth, for exactly here will the greatest and most immediate and permanent economics be found to justify the change.

The average plant below 2,000 hp is using not far from seven (7) pounds of coal per hp hour, and the labor and coal items approximate nearly 80 per cent of the total cost not far from \$120 per hp year.

Pulverized firing will cut these costs in half.

This general thought that small plants were not susceptible of this development has probably gained currency because of the excessive costs that have surrounded pulverized installations.

But central station ideas need not necessarily be applied to the small plants, nor need central station investments be invited.

Concretely, it is quite possible to re-organize a small plant of say four 250 hp—500 hp boilers, rebuild the furnaces so that they are adequate to burn pulverized coal efficiently, use much or all of the coal and ash-handling equipment with slight changes—install pulverizers, burners, feeders, fans and regulators—all at a cost well within the means of any company operating such a plant.

And when a small plant is so rebuilt, its operating labor costs, coal and overhead costs will compare very favorably with the efficient large plant.

Ultimate Possibilities.

Up to this point we have confined our discussion to stationary boilers; that problem is big enough in itself; but, if a slight digression is permissible, another most important phase of steam generation will be mentioned.

The locomotive is a power-plant and as such should not be lost sight of.

We will confine ourselves to the discussion of the American railroad as the statistics are more comprehensive.

Nearly 150,000,000 tons of selected coals are now destroyed annually in the 65,000 locomotives on our American rails—we say destroyed advisably, as the net mechanical equivalent received from this coal averages below 5 per cent. This low recovery is due to the combination of mechanical elements which go to make your locomotives, plus the difficulty of keeping these elements working even at the average efficiency. The boiler and furnace taken as a unit average closely around 50 per cent efficiency.

In other words, we find more than 50,000,000 tons of selected coals annually wasted and a good substantial part of the other 100,000,000 tons are burned just hauling this wasted third, and hauling back empty the millions of cars that carried the waste tons.

If this wasted third at \$4 a ton could be deducted from the debit side there would be \$200,000,000 to add to the net annual earnings of the hopelessly distressed United States Railways System. This 30 per cent increase upon the present annual \$700,000,000 would be of tremendous help to the 175,000 miles of road now in receivership or approaching receivership.

If, instead of "selected coal," the locomotive could be fired with ordinary grade slack available at its nearest point, at least, \$1 per ton cheaper, another \$150,000,000 could be saved.

By pulverizing this could be done.

It has been shown that the larger power-plants convert nearly 20 per cent of the heat value into actual mechanical equivalent. It has also been said that the locomotives destroy nearly 150,000,000 tons annually, converting less than 5 per cent of this into mechanical equivalent.

This means that every ton of coal fired in a power house equals four tons fired in a locomotive.

Visualized inversely, this would mean that our powerhouses and industries would require over 700,000,000 tons per year, if the same character of operation obtained that now penalizes the transportation plants.

Is it any wonder the railroads are having a hard time to live?

In view of the fact that this accumulation of waste value over the next ten years will approach a total running into billions when you include coal, transportation of loaded cars and empty returns, wages, repairs, etc.—it would look like an excellent investment to hazard the little money required on what little experimenting is necessary to apply pulverized firing to locomotives.

The problem presents no very great difficulties and direct firing will find its logical development. The total cost of equipment for enough locomotives to handle all traffic on this revised basis should not exceed \$350,000,000.

The Ideal.

Often times we are asked our reasons for the choice of pulverized firing and we reply, "Because it approaches the ideal."

You have all been in an average power house—you have gone through for an inspection, or, perhaps, it was necessary to investigate an accident or some safety recommendation, and you have noted the evident pride which was noticeable everywhere about the engine room and its appearance, in fact no structure could be more beautiful, architecturally, than the turbo-room of the modern power house like Philadelphia Electric at Chester, Colfax and Delray and dozens of others.

And, as you looked about you probably failed to notice that you weren't urged to be shown the boiler room. And, if you were shown the boiler room, it was not the same thing of joy that you found the engine room to be—it was just the boiler room, the necessary evil where millions of dollars, yes, hundreds of millions of dollars have been and continue to be wantonly wasted every year—just the boiler room, where a lot of grimy, dirty heroes eke out a miserable existence trying to interpret a lot of mysterious instruments into terms of thermal efficiency.

And then you saw the ash cellar, that bourne from

which no traveler returns "clean or dry;" that undesignated court of last resort where humans still perform the labor under the worst conditions it is possible to imagine. The ash cellar—depository of more waste wealth than the total value of all gold mined last year. (It is a fact that I have analyzed ash being carted away from big buildings in New York at a cost of about two dollars a ton which carried a higher percentage of fixed carbon than many western coals.)

I am speaking of the ash cellar in the average boiler house, but not of the ash cellar in a pulverized firing house. There, there is no ash cellar, and instead of being reluctant to show visitors the boiler house, or the ash cellar, that is the point of greatest pride, for it is the point of greatest comparison, as likewise the point of greatest saving.

And so, if the adoption of pulverized firing did nothing else, the elimination of the ash cellar, the ash problem, and the ash wastes would amply justify the method—for the engineer would have taken one step nearer to his ideal.

Most papers on pulverized firing have gone to elaborate lengths to prove higher efficiencies for this method of firing than for stoker firing. Numerous tests have been cited, showing such dizzy heights of efficiencies that you have all gasped in amazement. Such arguments have never interested me, except in a purely academic way, for I have seen many tests, and such arguments are a mere begging of the question. With your kind permission, as engineers we will omit the question of tests, and by means of a series of Socratic questions, see if we can possibly justify pulverized firing otherwise.

First, what would constitute your ideal power house; each of us who have to do with power houses must have formed an ideal.

If I may answer for myself and for you, the answer would appear something like this:

1. A control board so automatic, so flexible, so fool-proof, so safe that a high-school graduate could distribute the total load without the possibility of an error.
2. A generator, or generator capacity, which would deliver the maximum and minimum load requirements at practically a constant efficiency, automatic as to controls, and absolutely reliable.
3. A turbine or turbines which would operate on the minimum water rate over all loads, in which there could be no blading, or bearing, or governor troubles.
4. Auxiliaries so well proportioned and so well designed that the main units are adequately served, and at the same time there is maintained an ideal balance throughout.
5. Boilers, furnaces, coal handling equipment and house design so flexible that—the load on the turbine will be supplied with an automatically controlled supply of an exact temperature and pressure steam; steam generated in boiler units of such design and size that a maximum output can be obtained from a minimum hp rating, in boiler furnaces of adequate design to develop the entire Btu. value from the most available coal at that particular point. All movements of coal from the car or barges through the house to the completion of combustion shall be automatic, with likelihood of breakdown or interference reduced to the minimum, said movement and manipulation to be performed automatically and with the smallest number of human operatives.

The above total of work to be done with the least capital expenditure, to the end that interest on investment and depreciation items may harmonize with the lowest Btu. cost per kw hour produced.

Does this sound to you too ideal?

Now that we know what we want, we will go after it, and we will start at the coal-pile end.

What are the greatest losses? A glance at a series of heat balances and test sheets will show. The stack loss and the ash-pit losses.

When do these losses occur? The stack loss constantly but worst at cleaning periods.

What does the stack loss total?

In a 1,000 hp boiler, stoker-fired, the average ash drawn will contain 25 per cent unburned carbon, which means that 2,800 tons of ash must be handled per year and that 570 tons of carbon are lost.

In a 1,000 hp boiler, stoker fired, the excess air will average 50 per cent above the theoretical for combustion, which means that 131,000 tons of needless air are heated per year, and at least 4,000 tons of coal are wasted doing it.

Magnified into national losses, this means that more than 50,000,000 tons of coal are wasted annually heating excess air. About 20,000,000 tons of carbon equal to 30,000,000 tons of coal are lost through the ash pile.

If the coal fired in this country in steam plants and locomotives were pulverized, the loss due to excess air could be cut in half, and the loss due to unburned carbon in the ash eliminated.

Such a revolution would save some 80,000,000 tons of coal worth \$400,000,000. As only about 15,000,000 tons of coal are annually fired in pulverized form. At this point, I would like to refer you to a number of exhibits furnished by Mr. E. G. Bailey, an engineer whom most of you know has specialized in this field of investigation.

Just now we stated that ash-pit losses were highest at cleaning periods, and Mr. Bailey's charts prove that excess air losses are also highest at this period. Consequently, it must follow that the lower the number of cleaning periods, the lower the losses.

Pulverized furnaces have no cleaning periods, or can be so designed, but Mr. Bailey's charts show the reverse where the stokers are used.

It is not necessary to detail other furnace and boiler losses; there is small difference between radiation, soot accumulation, etc., in stoker firing and in pulverized firing.

We have all heard a lot of the glittering generalities about the possibilities of this system or that system—we have made tests for efficiency, and we have carefully scrutinized the many tests made by other people, but all that does not afford any of us much comfort in the solution of our own particular problem.

We all know where we would like to arrive—but to find the starting point is a most difficult matter.

With your permission, I will give two concrete applications, either of which may serve as your "starting point."

Please understand that efficiency in either of these illustrations is not the mark we're shooting at—our most obvious aim is immediate reduction of total operating costs, increase of capacity, reduction of labor without huge appropriations. We will consider efficiency later.

The first problem is concerned with an old boiler house consisting of twenty (20) aged B. & W. type boilers (250 hp) fired by three different types of obsolete stokers—all natural draft—developing approximately 3,000 hp hourly at a yearly hp cost of nearly \$100.

Coal handling, ash handling and producing labor charges were out of proportion to the product delivered. The best thing to do, of course, is to scrap the entire equipment, and replace it with new boilers.

With this thought in mind, estimates are made, bids are received and we find that it will cost about \$300,000 to do the job. This means an appropriation, which under the existing trade conditions is open to considerable delay.

The immediate solution is to concentrate upon the fewest number of selected boilers; equip these with combustion chambers of sufficient capacity to operate at high ratings, that is, high in relation to former operations; install the cheapest available pulverizing equipments and then scrap the remaining units.

Practice has shown that six (6) boilers so equipped will deliver the total amount of steam—at a total cost for one year of about 60 per cent of former costs.

To do this reconstruction complete, costs total less than \$30,000. You can all figure the return on the investment for yourselves.

The second problem had to do with a large plant operating a large number of scattered boiler houses, inter-connected with steam lines—all stoker fired, all mechanically equipped for coal hoisting and conveying, ash-handling, etc., but all boilers limited in their capacities by the size and character of their stokers, and by the natural draft limitations from which most plants suffer.

Fortunately, among this group of boiler houses was one house of ten (10) 1,000 hp boilers not very old.

Analysis showed that these ten boilers could be re-equipped to produce the total evaporation required to operate this plant, and the savings would warrant whatever types of pulverizing equipment this 17,000 hp production would demand.

Analysis of the factors comprising the charges against coal and ash handling from the yard to the yard may be of interest with a comparison of like charges with pulverized equipment:

	Former Per Ton	Pulverized Per Ton
Yard switching	\$.22	\$.22
Coal unloading and distribution.....	.23	.03
Firing	.17	.01
Ash handling	.26	.02
Repairs to equipment.....	.10	.07
Power, stokers, hoists, conveyors, etc.....	.105	.00
Power pulverizers, exhausters, etc.....	...	.22
	<u>\$1.085</u>	<u>\$.57</u>

Estimates of various types of pulverized equipment together with the rebuilding of boiler furnaces, etc., indicated a cost ranging from \$150,000 to \$350,000. Between these two figures there is a wide latitude in selection of standard equipment; any combination of which can be depended upon to produce this evaporation: at least the same rate of efficiency as present operation.

You can all figure the saving effected by multiplying 200,000 tons by \$.51.

Pulverized Firing as an Auxiliary or Emergency Fuel.

Iron and steel mill practice has witnessed a broader application of waste heat utilization than found in any other industry. This is, of course, natural, as there are here found more waste heats to utilize than elsewhere.

Among the various types of waste heats, that from the blast furnace plays a leading part, and has been more consistently studied and developed than any other. (Apologies to Mr. McDermott of the Illinois Steel Company.

Blast-furnace gases are essentially a low quality, large volume problem.

The solution has been intimate ignition surfaces, low velocities through ample combustion chambers. Control of the excess air supply, through effective regulating devices has been found imperative.

Where the combination of the above elements has been assembled, remarkable results have been obtained. Plants are now operating on blast-furnace gas with a constant CO_2 —25.5 per cent; steam pressure a constant 250 pound; steam temperature a constant 560 degrees—superheat invariable, and the furnace pressure a constant ZERO.

Such operation, however, implies a fairly constant supply of gas at nearly 3-inch pressure.

In many blast-furnace operations, electric power is developed to meet an outside constant load, this in addition to the usual gas which is required for furnace operation, blowing, stoves, pumps, etc. As blast furnaces are far from perfect operating units—due to internal conditions—(variables), the supply and pressure of gases will fluctuate rapidly and seriously.

This fluctuation is usually taken care of by the use of an auxiliary fuel. This fuel may be coal, hand-fired or stoker, coke-dust or tar, or pulverized coal. Pulverized coal is nearly ideal for this purpose.

Pulverized coal can be safely carried in suspension in a volume of air equal to about 25 per cent of that required for combustion.

A cubic foot of such mixture is almost equal to a cubic foot of average unwashed blast-furnace gas—about 90 Btu.

In other words, the combustion problem, as to ignition, furnace volumes, carried over incombustible burners, volume air supply are so similar that the combination is an excellent solution of an auxiliary fuel for this purpose.

The large Ladd boilers at the Ford plant in Detroit, so equipped, will furnish a wonderful demonstration of this practice.

Auxiliary Fuel in Central Station Practice.

Central station practice is essentially a peak-load operation.

To insure against this peak-load maximum, greater than average stoker and fan capacity must always be provided, maintained and carried as investment and depreciation.

The only limit to boiler capacity seems to be grate area, and the limit of efficient operation seems to be the amount of coal per square foot of stoker area which can be burned with a maximum blast pressure and still keep the fuel on the grates and not slag tubes, etc.

Stoker performance seems to have nearly reached its limitations.

Pulverized fuel offers an excellent field for development in this line.

This seems to be the opinion of very conservative engineers who have given the subject close thought.

There are many other fields in which some such combination may work out advantageously—various applications will suggest themselves to your various minds.

Among others, stand by boilers for hydro-electric plants.

In conclusion let us review.

Pulverized coal was originally an ideal, and like any other ideal will persist. Rudimentary chemistry taught us that fuel combustion was clearly imperfect reactions—and the farther away from the atom we got, the more imperfect was the reaction to be expected.

Conversely, the nearer to the atom we brought our fuel the more nearly would we approximate perfection.

Pulverizing was the method of the laboratory calorimeter.

But in the laboratory costs are not a factor, while in industry, costs are the base of the pyramid.

Naturally, the application of a costly process, for pulverized fuel has always been relegated to that class, was first considered in processes or industries where fuel costs were relatively small, and has slowly invaded other fields more recently opened up by rising costs of labor and fuel.

Pulverizing is not a new art in the mining industry or in cement manufacture—there it is a standard practice, and has been for years.

Nor is there any novelty in its application to open-hearth, puddling furnaces, or heating furnaces.

I have referred to other industries to show the psychological connection between many of the present pulverized systems installed under boilers and their origin.

Metallurgical operations frequently require very close specifications in fuel and its preparation, and to overcome those narrow limitations, a variety of systems have been developed.

When boilers were to be equipped, such complete systems were naturally commandeered. It was not a question of equipment to do a given work—it was an equipment which was known to do a certain work of an apparently similar kind. Engineers are human, and like most human beings, they follow the line of simplest attack.

Now, in the metallurgical field, costs could be high and still not be prohibitive, because pulverized fuel had only to compete with other expensive applications, such as oil, tar, producer gas, by-product gas, etc., and the fuel was only a comparative item in the production of a profitable tonnage. But under the boilers, the competition of mechanical stokers develops an entirely different picture. The entire job must be done cheaply for mechanical stokers are now very efficient.

Just at this point we find the line of departure between pulverized coal in metallurgy and pulverized coal as a power fuel.

Over eighty years ago patents were allowed on a practical application of pulverized firing to boilers: twenty years ago complete plans were drawn for larger commercial operations.

PRODUCTION TOPICS

WAGES IN THE UNITED STATES AND FOREIGN COUNTRIES.

(Prepared for the use of the Committee on Ways and Means, House of Representatives.)

IRON AND STEEL INDUSTRY. UNITED STATES.

Average earnings per week of furnace and mill workers, 1920.*

Blast furnace and rolling mill workers.....	\$43.12
Rates per ton for workers in bar iron plants.†	
Puddling, 1895	\$ 5.50
Puddling, 1920	16.00

*The Iron Age, 1920.

†U. S. Tariff Commission survey, 1921, p. 20.

ENGLAND.

Rate per week (47 hours) for common labor, 1921.‡

Common labor	70s. 4d. = \$12.52
Unemployment decreased 1.3 per cent in month of December, 1920.	

Short time is general throughout industry, many works being closed down.

Rates per ton in bar-iron plants, 1907, 1913, and 1920.

Puddling:	
1907°	\$2.33
1913§	2.74
1920°	\$7.50-8.27

Rates per week in various iron and steel trades, 1920.¶

Occupation.	Location.	Month.	Rate.
			s. d.
Iron molders	Carlisle	October	88 10½ = \$15.46
Do	Huddersfield	Do	90 6 = 16.05
Do	Otley	Do	91 8 = 16.25
Do	Newport	September	100 0 = 17.40
Coppersmith (ship)	London	July	105 0 = 18.27
Pattern makers	Edinburgh	August	96 9 = 16.85
Fitters	Shops Great Western R. R.	August	} 99 7 = 17.33
Turners	Do	Do	
Smiths	Do	Do	
Coppersmiths	Do	Do	
Boilersmiths	Do	Do	
Fitters	Todmorden	June	} 88 3 = 15.35
Turners	Do	Do	

¶Department of Commerce.

Rates per week for women and girls in malleable iron plants, 1920.¶

Occupation.	14 years old	18 years old	20 years old
Molders	\$3.58	\$7.20	\$8.00
Dressers	3.58	7.20	8.00
Foundry wheelers	3.58	7.20	8.00
Sand blasters	3.58	7.20	8.00
Core makers	3.58	7.20	8.00
Examiners	3.58	7.20	8.00
Sand wheelers	3.58	7.20	8.00
Emery wheel dressers	3.58	7.20	8.00
Power pressers	3.58	7.20	8.00
Polishers	3.58	7.20	8.00
Capstan lathe workers	3.58	7.20	8.00
Hand pressers	3.36	6.65	7.42
Machine workers	3.36	6.65	7.42
Varnishers	3.36	6.65	7.42
Rough warehouse workers	3.36	6.65	7.42
Bronzers	3.36	6.05	7.42
Wrapping workers	3.15	6.40	7.20
Warehouse workers	3.15	6.40	7.20
Lacquers	3.15	6.40	7.20

¶Labour Gazette, September, 1920.

†Hugh D. Butler, American trade-commissioner.

°U. S. Tariff Commission survey.

§Commerce Report, June 27, 1913.

Minimum rate per week (48 hours) in Birmingham wire-working plants, 1920.¶

Occupation	Per Hour s. d.	Per Week
Wire workers	1 8	\$15.30
¶Labour Gazette, August 1920.		

FRANCE.

Rates per day in iron and steel mills 1913 and 1920.¶

	1913	
	Francs	
Highly skilled workers (piecework)	11.0-15.0	\$2.12-\$2.90
Skilled workers in various lines....	8.0-10.0	1.55- 1.93
Ordinary workmen or helpers.....	3.5- 4.5	.68- .89
	1920	
	Francs	
Highly skilled workers (piecework)	25-40	\$2.00-\$3.20
Skilled workers in various lines....	16-19	1.28- 1.52
Ordinary workmen or helpers.....	12-16	.96- 1.28
¶J. F. Butler trade commissioner.		

Highly skilled workers paid on a piece basis received from 11 to 15 francs per day in 1913. These men now earn from 25 to 40 francs a day. The Comité des Forges de France the central organization of the French iron and steel industry which furnished the above information pointed out that under present economic conditions it is necessary to revise wages constantly. Under these circumstances it is impossible to predict the level which may be reached before wage conditions become stable.

Rates in Grenoble snap-fastener establishments, March 1, 1921.

	United States
	—Francs— Currency
Factory girls per day	7.76 \$0.54
Factory women do..	9.36 .66
Common labor do..	11.20- 15.20 \$0.78 1.06
Machinists do..	16.00 26.00 1.12 1.82
Foremen per month	700.00-1,000.00 49.00-70.00
Office girls do..	300.00- 350.00 21.00-24.50
Bookkeepers do..	400.00- 600.00 28.00-42.00
Foremen of plating department	800.00 56.00

GERMANY.

Rates per day (8 hours) in rolling mills, Dresden district, December, 1919.

Rolling mill workers	\$0.40
Furnace workers	.40
Machinists and blacksmiths.....	.38
Women workers	.14

Average rates per day (8 hours) in rolling mills in the districts of Breslau and Cologne.¶

	July, 1914	December, 1919 (8 hours)
Boys	\$0.77	\$0.29
Unskilled	1.32	.52
Semiskilled	1.54	.60
Skilled	2.09	.65

¶Official German report (Jahresberichte der Gewerbe Aufssichtsbeamten und Bergbehörden.)

NEWS OF THE PLANTS

The American Steel Rolling Company, 1203 North Charles Street, Baltimore, Md., is considering plans for the erection of a new plant at Eighth and Monument streets, to be devoted to the manufacture of iron and steel rods, concrete reinforcing bars, and kindred products. It is proposed to develop a capacity of about 15,000 tons of material per annum. The works will include a small open-hearth furnace. The plant will utilize scrap metal. Reuben S. Baldwin is general manager. W. Y. Schall is superintendent in charge of operations.

The Columbus Forge & Iron Co., West First avenue, Columbus, Ohio, manufacturers of anvils, forgings, and other iron products, has plans under way for the construction of two additions to its plant. The buildings will be one-story, on site at the foot of West First avenue, 110 x 125 feet, and 70 x 200 feet, respectively, estimated to cost about \$85,000. Braun, Fleming, Knollman & Prior, 233 South High street, Columbus, are architects.

The Steel Fabricating Corporation, Harvey, Ill., manufacturer of steel buildings, has completed the erection of a new plant at Michigan City, Ind., and the present works will be removed to this location. The new plant aggregates about 175,000 square feet of additional floor space with approximately triple output over the former plant. Headquarters will be established at the new location.

The Kansas City Wire & Iron Works, Kansas City, Mo., has plans under way for the rebuilding of the portion of its plant, recently destroyed by fire, with loss estimated at \$80,000, including machinery and equipment.

George Baker & Sons, 103 Belmont street, Brockton, Mass., manufacturers of wire nails, rivets, studs, etc., will occupy a new plant now being erected on North Monticello street by the Baker Realty Company and affiliated organization. The foundation work for the new factory has been completed and erection of superstructure will be inaugurated at once. It will be one and two stories, 93 x 225 feet, and is estimated to cost about \$75,000. George Howard & Sons, Inc., 633 Warren avenue, Brockton, have the building contract. George L. Falk, 153 Main street, Brockton, is architect.

The Dominion Steel Corporation, Sidney, N. S., is arranging for the immediate resumption of operations at its local plant on a full-time basis. The company recently placed a wage decrease of 20 per cent into effect and has now proposed an additional 10 per cent reduction to the men. The plant recently has been working on a basis of from one to three days per week.

The Seaboard Steel & Iron Corporation, Baltimore, Md., recently organized under Maryland laws with a capital of \$200,000 to manufacture iron and steel products, has acquired property at Paca and West streets, as a site for its proposed new local plant. Plans will be placed under way at once, and details are being arranged. William F. Holl and Frederick W. Lauterbach, Gaither building, Baltimore, represent the company.

The Guaranty Iron & Steel Company, 2851 West Lake

street, Chicago, Ill., have taken bids for the construction of an addition to its plant for increased production. The extension will be one-story, 100 x 200 feet, and is estimated to cost about \$65,000. It will be located on West Lake street. J. A. Taggart, 19 South La Salle street, Chicago, is architect. R. J. Ross is president.

The Inland Steel Company, Chicago, Ill., has acquired a tract of land aggregating close to 600 acres in Porter County, Ind., adjoining a recent acquisition of about 250 acres in this district. The property is in the vicinity of the works of the Indiana Steel Company, Gary, Ind., and will be used by the new owner, it is understood, for the construction of a new plant. No immediate plans have been arranged for construction.

The American Steel & Wire Co., 94 Grove street, Worcester, Mass., has completed foundation work for the proposed addition to its South Works, and erection of superstructure, brick, steel and reinforced concrete, will be handled by day labor. The structure will be three-story, 114 x 120 feet, and is estimated to cost about \$150,000. C. E. Goodrick, company address, is engineer.

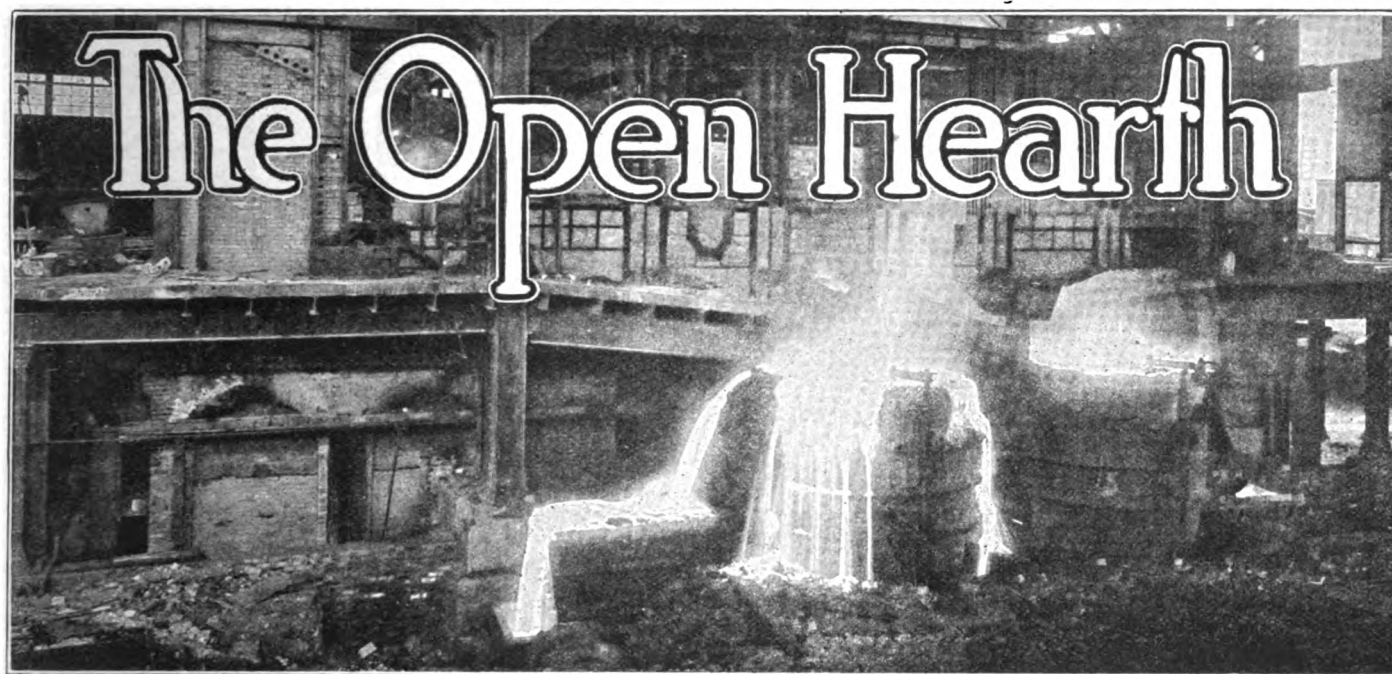
The Oliver Iron & Steel Co., Pittsburgh, Pa., will soon commence the construction of a new four-story plant at Muriel and South Twelfth streets. Plans for the structure recently have been filed. It is estimated to cost about \$100,000, including certain equipment.

The Richard DeCou Company, Twelfth and Noble streets, Philadelphia, Pa., manufacturer of iron and steel shapes and affiliated products, has plans under way for the establishment of a new scrap-cutting and material handling yard on a thirty-acre site on the Schuylkill River. Iron working and cutting shops will be erected, and material loading and unloading equipment installed. The storage shops will be provided with material-handling equipment. It is planned to inaugurate initial work on the new plant at an early date.

The Nagel Steel Company, Pottstown, Pa., is perfecting plans for the erection of a new steel and iron works on a 200-acre tract of land, known as the Brooke Farm, near Pottstown. The plant will include open-hearth works, rolling mill, finishing mills, etc., with a number of large modern buildings for the different departments. A bond issue will be arranged to carry out the construction and machinery installations. The company has branch plants at Seyfert, Pa., and Rahway, N. J., respectively. L. F. Nagel is president of the company; E. H. Heydt, treasurer, and R. P. Cairnes, general purchasing agent.

The American Car & Foundry Company, 165 Broadway, New York, has plans under way for the rebuilding of the portion of its plant at Huntington, W. Va., destroyed by fire, May 19, with loss estimated at about \$50,000, including equipment.

A. M. Castle & Co., 715 North Morgan street, Chicago, Ill., iron and steel products, will take bids at an early date for the construction of a new one and two-story building on Blackhawk street, in the vicinity of the Chicago river.



J. M. Davis, formerly vice president of the Baltimore & Ohio, has been elected president of Manning, Maxwell & Moore, Inc., 119 West Fortieth street, New York City, to succeed the late A. J. Babcock. Mr. Davis was born on November 5, 1871, and began railway work in 1888 as a freight brakeman on the San Antonio & Arkansas Pass. From September, 1891, to 1900, he served consecutively as stenographer to the superintendent of the Gulf, Colorado & Santa Fe; chief clerk to the superintendent of the Mexican Central; clerk in the general manager's office of the Great Northern; assistant superintendent and later superintendent of the Great Northern. In 1900, he went to the



J. M. Davis.

Erie as superintendent at Scranton, Pa., subsequently serving as superintendent of the Union Steamboat Line of the Erie, at Buffalo, N. Y., and as superintendent of the Allegheny division of the Erie. He returned to the Great Northern in 1903 as superintendent, and in 1905 was promoted to assistant general superintendent of the Central district. In 1907 he went to the Oregon Short Line as assistant general superintendent, and was subsequently made acting general superintendent and later general superintendent. In 1920 he was appointed general superintendent of the Central district of the Southern Pacific, with headquarters at San Francisco, Cal. He entered the service of the Baltimore & Ohio on January 1, 1914, as assistant general manager at Cincinnati, Ohio, of the Baltimore & Ohio Southwestern—Cincinnati, Hamilton & Dayton, and later in the same year was promoted to general manager of these lines. In July, 1916, he was appointed vice president in charge of operation and maintenance of the Baltimore & Ohio System, with headquarters at Baltimore, Md., and held that position until July 1, 1918, when, under federal control of the railroads, he was

appointed manager of the New York properties of the Baltimore & Ohio, including the Staten Island lines. In September, 1919, he left the Baltimore & Ohio to become president of the Rock Hill Iron & Coal Company and associated corporations, including the East Broad Top Railroad & Coal Company, with offices at New York.

V V

Dexter S. Kimball, manager of the American Society of Mechanical Engineers and dean of the College of Engineering, Cornell University, was nominated for president of the society at its spring meeting held in Chicago, May 23 to 26. Mr. Kimball has been active in the work of the society and a member since 1900. He is also vice president of the Federated American Engineering Societies.

V V

Bradley Stoughton's resignation as secretary of the American Institute of Mining and Metallurgical Engineers, which office he has held since 1913, has been accepted by the institute's board of directors. He will terminate his services after a successor is elected and has become familiar with the work. The directors of the institute, in accepting Dr. Stoughton's resignation, formally expressed their recognition of the benefits which his work has brought to the institute.

V V

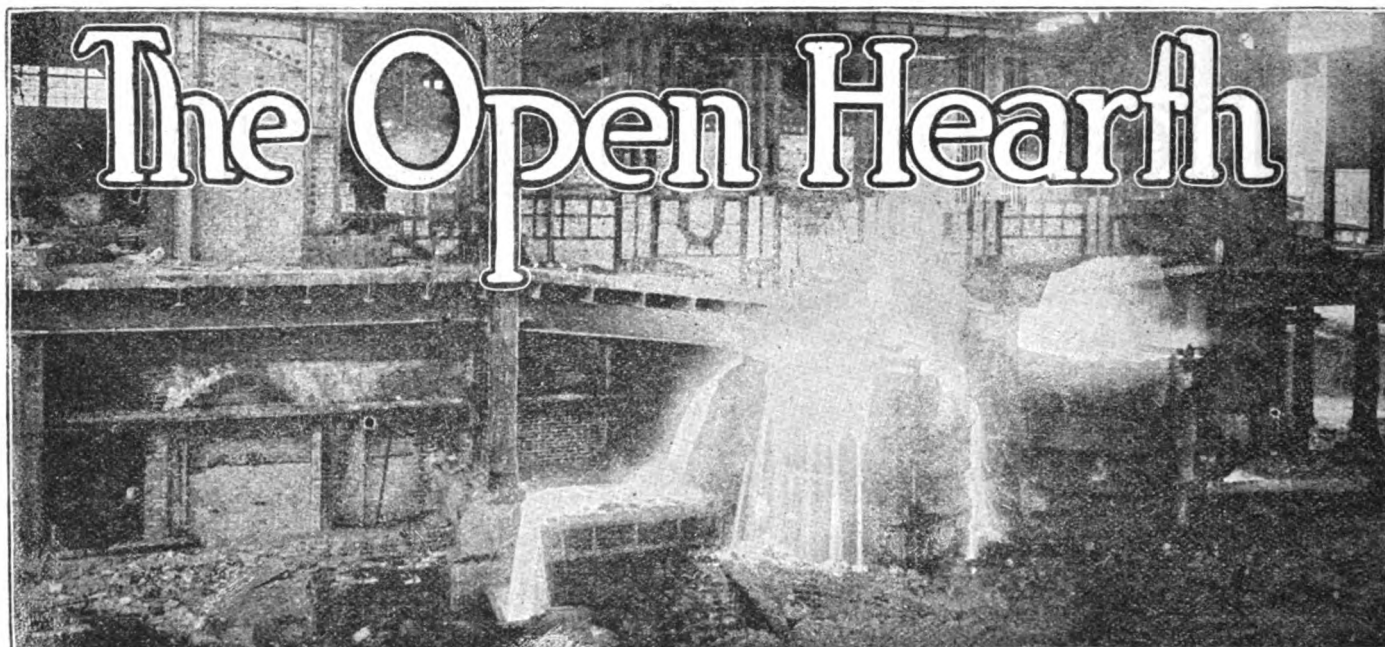
Clement F. Poppleton, 805 Duquesne way, Pittsburgh, was recently appointed consulting engineer for the Iron & Steel Products Co., 230 Fifth avenue, and the Hanlon-Gregory Galvanizing Co., both of Pittsburgh.

V V

Roy G. Owens, vice president in charge of sales of the Lakewood Engineering Co., Cleveland, has resigned. He had been prominent in the affairs of the company since the consolidation of the Milwaukee Concrete Mixer Company with it in 1917.

V V

W. L. Goodhue, who has been district manager in charge of the Dover and New Philadelphia, Ohio, plants of the American Sheet & Tin Plate Co., for the last four years, has been transferred to Farrel, Pa., where he has become manager of the company's Mercer works. William L. Davis, superintendent of the New Philadelphia plant, and William



Weichsel, superintendent of the Dover plant, have become managers of these plants.

✓ ✓

John McKay has retired as superintendent of the McDonald mills of the Carnegie Steel Company, Youngstown, Ohio, and has gone to his dairy and stock farm near Greenville, Pa.

✓ ✓

N. W. Kistler has resigned from the safety department of the Youngstown Sheet & Tube Co., Youngstown, Ohio, to become safety inspector of the Whitaker-Glessner Steel Co., Portsmouth, Ohio. In his new capacity, Mr. Kistler will have charge of the fire, police, welfare employment, sanitation and hygiene and safety departments.

✓ ✓

William Anglin resigned recently as superintendent of the bar mills of the Pittsburgh Crucible Steel Co., Midland, Pa.

✓ ✓

George S. Vail has been elected general manager of Arthur G. McKee & Co., Cleveland, blast furnace, steel plant and power plant engineers. The position is a new one and Mr. Vail, who has been with the McKee Company a number of years, has also been made a director of the company, the board having been expanded to five members.

✓ ✓

A. P. Van Scharck, who has been manager of the American Chain Company for about a year and a half, has been appointed general sales manager of the Page Steel & Wire Co., Pittsburgh, and Monessen, Pa., and affiliated interests. Mr. Van Scharck succeeds E. C. Sattley, who now is president of the Iron & Steel Products Co. W. T. Pyle, who has been connected with the Page Company for a number of years, has been appointed assistant to Mr. Van Scharck.

✓ ✓

George C. Thayer, former general manager of the Hariman plant of the Merchant Shipbuilding Corporation, Bristol, Pa., has been appointed assistant to the vice president with office at Chester, Pa. L. D. Keller has been appointed executive assistant to the vice president.

✓ ✓

J. E. Thropp, Jr., who has been blast furnace superintendent at the Columbus, Ohio, plant of the American Rolling

Mill Company, Middletown, Ohio, for the past three and a half years, has resigned.

✓ ✓

L. A. Lambing was recently appointed superintendent of the open-hearth department of the Pittsburgh Crucible Steel Company, Midland, Pa. Mr. Lambing was formerly assistant superintendent of the open-hearth department of the Homestead plant of the Carnegie Steel Company.

✓ ✓

Ernest F. Perkins, metallurgist for the Oliver Chilled Plow Works, South Bend, Ind., has been appointed instructor in chemical engineering in the School of Engineering of Northeastern College, Boston. Jos. W. Zeller, who has been engaged in engineering work in Worcester, Mass., the past year, has been appointed assistant professor of mechanical engineering in the same school.

✓ ✓

F. C. Carts has been appointed general inspector and has been transferred from the Columbiana, Ohio, works of the Columbiana Foundry Company to the McKeesport, Pa., works.

✓ ✓

James A. Farrell, president United States Steel Corporation, has been elected member of the board of regents of Georgetown University, Washington, succeeding the late Anthony Hirst, Philadelphia.

✓ ✓

William N. West, formerly superintendent of the mills and roll shop of the Elyria Iron & Steel Co., Elyria, Ohio, has been appointed general superintendent, succeeding Walter Ferrier, who has severed his connection with the company.

✓ ✓

J. C. C. Holding, appointed recently as manager of the structural division of the Midvale Steel & Ordnance Co. and the Cambria Steel Company, with headquarters in Philadelphia, is a graduate in civil engineering of the Rose Polytechnic Institute, Terre Haute, Ind. Immediately upon graduation he became connected with the civil engineering department of the Johnson Co., now the Lorain works of the National Tube Company. He later spent several years in the structural drafting rooms of the Shiffler Bridge Works and the Keystone Bridge Works, Pittsburgh.

Some Pointers on By-Product Coke Oven Operations

A RECORD IN SHUTTING DOWN BY-PRODUCT COKE OVENS.

By J. M. Hastings, Jr.

In these days of business depression, many industrial plants are closing down to await a better demand for their products. Among these are many blast furnaces and steel plants, but the impression seems to have gained considerable credence that a by-product coke oven plant cannot be allowed to become cold, without serious injury and more or less complete rebuilding before it can be started again. Some owners are even going to heavy expense to keep their oven plants hot, or are selling coke at a serious loss to avoid a shutdown.

A report recently received from a plant of by-product ovens near Wheeling, W. Va., may be of interest to by-product oven owners, as it shows that a correctly designed plant may be shut down completely without serious injury.

In 1898, a plant of 60 Semet-Solvay ovens was built for the Riverside Iron Works, now owned by the National Tube Company, at Benwood, W. Va., just outside of Wheeling. Two years later, 60 more ovens were added. The plant was built on the flat land along the Ohio River, and although the records of high water were carefully studied for a long period back, the progressive denudation of the forests made these records of little value, and three years after the first ovens were started, the plant was put out of operation by high water. During the twenty years from April 24, 1901, when this first shutdown occurred, to March 16, 1921, the date of the most recent shutdown, the Benwood coke oven plant has been closed down and started up again twenty distinct times.

Seven times in that period the Ohio has flooded the district and effectively put the ovens out of commission. Most of these interruptions were for relatively short periods, although in each case the plant was kept in operation until water entered the waste heat flues. In March, 1907, however, flood water was high enough to enter the sole flues and reach the oven floors proper, causing an eighteen-day shutdown, and in April, 1913, the worst flood in the history of the river brought the water into the lower heating flues fifteen inches above the floor of the ovens. On this latter occasion a shutdown of twenty-five days resulted, largely because natural gas for starting up again was not available for some time after the flood subsided.

In addition to interruptions caused by floods, the plant has been down four times on account of coal shortage, twice for repairs to the hydraulic mains and seven times on account of business conditions. Duration of shutdown from this last cause has ranged from one month in 1914 to a year and seven months in 1907 to 1909.

During its entire twenty-two and a half years' existence, the Benwood plant has been shut down 1,958 days, or a total of five and one-third years up to March 16 of this year, since which date it has again been cold. Several other Semet-Solvay plants have been shut down for varying periods, but none have approached this record and probably none ever will, due to the peculiar circumstances at Benwood.

Notwithstanding this rather remarkable record of shutdowns, the present condition of the plant shows that it has

suffered no serious damage. Of course these extraordinary and repeated stresses on such a large amount of brickwork cannot be encountered without some injury and expense for repairs. But the construction of this type of oven, with the well-known strong division wall between the ovens, was so substantial that any injury occasioned by these vicissitudes has been of a minor nature, as is shown by the following records.

Of all the ovens built in the United States, No. 30 oven in Block No. 1 at Benwood holds the record for low repair costs. This oven has gone through all the vicissitudes mentioned, has been in operation seventeen years and out of run twenty times for a total of over five years, and to date has required no replacements whatever in its lining or brickwork. No. 60 oven in Block No. 2 is a close second, having required less than \$20.00 expense for brickwork repairs. It should be further noted that the two ovens mentioned at Benwood are both end ovens, which is the point where injury to the structure of the blocks often first appears. The repair records of these two ovens are of course exceptional, but the record of the entire plant has been remarkable, despite the numerous interruptions.

In addition to these repair records on the ovens, the yields obtained at the Benwood plant have been very satisfactory and compare favorably with those from the best modern plants. For the five-year period from January 1, 1915, to January 1, 1920, during which time the plant enjoyed fairly continuous operation, the average results were as follows:

Analysis of Coal Charged

Volatile	29.9%
Fixed C.	62.2%
Ash	7.9%

Yields Obtained

Total coke	78.2%
Sulphate of ammonia.....	24.5 lbs. per ton
Light oil	3.11 gals. per ton
Tar	10.0 gals. per ton

These records show conclusively that that plant has not suffered by reason of its many shutdowns and the same should be true for any correctly designed oven plant. Of course it is necessary to exercise care and to take certain precautions when closing down a coke oven plant for an indefinite period. The process is, in general, just the reverse of that employed in starting up a block. The heats should be lowered gradually by a gradual reduction in the supply of fuel gas, so that the contraction of the block will take place slowly and regularly. As this contraction progresses, the tie rods must be readjusted and a close watch maintained to guard against cracks developing.

If the coke is left in the ovens, as is sometimes done when a long shutdown is not anticipated, the greatest care must be used in sealing the ovens as nearly airtight as possible. The door frames must be kept tight against the brickwork, uptake pipes maintained in proper position and charging hole covers sealed tight. With an experienced operator in charge, experience has shown that there is no reason why a block of ovens of correct design cannot be shut down for a longer or shorter period, without extraordinary labor or heavy repair expense on starting up.

TRADE NOTES

Charles Copeland, assistant treasurer, has been elected a member of the Board of Directors and secretary of the E. I. du Pont de Nemours & Co., to fill the vacancies caused by the death of Alexis I. du Pont.

The Chateaugay Ore & Iron Co. has engaged Freyn, Brassert & Co., engineers, Chicago, for the work of remodeling its blast furnace plant at Standish, N. Y., and for the construction of a sintering plant at its mines at Lyon Mountain, N. Y. The blast furnace stack is to be enlarged in capacity and the plant modernized by the addition of mechanical handling equipment. The sintering plant at Lyon Mountain mines will supplement the ore concentrating plant and will produce a low phosphorous copper-free sinter for shipment to the blast furnace at Standish.

In order to handle more satisfactorily its growing detinning business in the West, the Metal & Thermit Corporation has constructed and will shortly place in operation in South San Francisco, Cal., a large new plant for the production of detinned billets, in addition to the detinning plants already operated by this company for several years at Chrome, N. J., and East Chicago, Ind.

Mr. J. B. Johnston, vice president and general manager of The Standard Scale & Supply Co., Pittsburgh, Pa., has resigned.

Willard C. Brinton, president of the Terminal Engineering Company, Inc., makes the following announcements: J. F. McGonigal, mechanical engineer, formerly of the Foamite Company, and J. H. Potter, mechanical engineer, a graduate of New York University, have joined the organization. M. E. Lyle, for many years with the Columbia Graphophone Company, has been elected a vice president and is directly responsible for new business. M. E. Peck has been elected secretary and assistant treasurer.

The M. J. Dougherty Company, piping fabricators and contractors of Philadelphia, announce a change of address of their Atlanta representative's office address to Candler Annex. This office is in charge of Messrs. McKee and Wright, who have had an extensive experience in the engineering field and are widely known in the South, having been actively engaged in the power field for nearly a score of years.

The International Nickel Company, 67 Wall street, of which W. L. Wotherpoon is chief engineer and Frank I. Ellis, 2126 Farmers Bank Building, Pittsburgh, Pa., consulting engineer, have placed the contract for 2-pair, 2-sheet and 6 annealing furnaces with the Surface Combustion Company, 366 Gerard

avenue, Bronx, New York City, through the latter's Pittsburgh office, 927 Union Arcade. These furnaces will be fired by the Surface-Combustion process, using natural gas, and will be installed in the International Nickel Company's new plant at Huntington, W. Va.

TRADE PUBLICATIONS

Dayton-Dowd Company, Quincy, Ill., has issued Bulletin No. 244, covering advances made in design and application of their centrifugal pumps. It contains photographs and tests covering the use of these pumps.

Hyatt Roller Bearing Company has issued a complete truck report, the nature of which shows the advantages of using roller bearings in industrial tractors and trucks.

Atlas Valve Company, Newark, N. J., has issued Bulletin No. 5, covering the Victor damper regulator No. 3, high pressure. This regulator is designed for boiler pressures up to 250 pounds. This bulletin will be sent out upon request.

Geo. J. Hagan Company has issued Bulletin L. F. 103, entitled "Liquid Fuel Burners for the Generation of Steam." This booklet is very complete in every detail and shows a number of cross-sections of various burner settings.

Steam Tables for Condenser Work.

The Wheeler Condenser & Engineering Co., Carteret, N. J., announces the publication of the 1921 edition of its popular "Steam Tables for Condenser Work." This is the sixth edition of a work which for many years has been widely used by engineers dealing with the condensation or evaporation of steam. The tables are in a very handy book form, pocket size. The properties of saturated steam are tabulated from 29.8 inches vacuum to atmospheric pressure in increments of tenths of an inch referred to a 30-inch barometer. The values were especially calculated for this book by Professor Marks. As it is customary in vacuum work to read vacuum in inches of mercury, this is superior to the old method of giving absolute pressures in pounds per square inch. Above atmospheric pressure the increments are in pounds gage. The book explains how measurements are made by means of the mercury column and barometer, and gives constants and tables for making corrections. Corrections for the thermal expansion of mercury, for the relative expansion of mercury and brass scale, and other corrections are included.

"C-H Elevator Controllers" is the title of a 40-page book just published by The Cutler-Hammer Manufacturing Company. In addition to a description of the various C-H elevator controllers and accessories, the book contains a dis-

cussion of the types of motors best suited to elevator work and an outline of the usual method of selecting motors of the right horsepower and starting torque to insure satisfactory performance. Tables giving motor, fuse and wire ratings are also included. An index makes it easy to turn to any particular section of the book.

The American Steel & Wire Co., New York, has issued a 50-page booklet which contains a history of slack cooperage as well as a catalog of twisted splice and electric welded wire hoops manufactured by the company. The booklet details the various products of the American Steel & Wire Co. for the cooperage industry, together with the method of using these products.

Air and steam motors, pneumatic hoists, contractors' hoists, crane hoists, hoisting engines, swinging engines, motor crabs, electric hoists, steam steering gears, spud hoists, capstans, windlasses, fish net lifters, etc., are described and illustrated in a 72-page illustrated booklet recently published by the Dake Engine Company, Grand Haven, Mich. This booklet describes the various products of the company in detail, giving specifications, etc.

A large 40-page illustrated booklet has been published by the Cutler-Hammer Manufacturing Company, Milwaukee, in which elevator controllers are described and illustrated. According to the booklet the salient features of these controllers are renewable carbon to copper power contacts; a constant time element type of acceleration; quiet, sure-operating magnetic contactors; simple construction with few auxiliary interlocking contacts. The controllers are described in detail.

The Electric Hoist Manufacturers' Association, New York, has published a 12-page illustrated bulletin in which approved applications of electric hoists are given. The list to which such hoists have been put to use successfully includes automobile manufacturing plants, airplane factories, bolt, nut and screw plants, brass and copper mills, brick yards, by-product plants, car manufacturing plants, repair shops, chemical plants, electric light and power plants, enameling plants, forging plants, foundries, and numerous others.

The Sanitation Corporation, New York, has published an interesting booklet entitled "The Sanitation of Cities," in which the sewage disposal problems of large municipalities, and small ones as well, are described. The booklet is printed on heavy coated stock, is profusely illustrated with cuts of various cities of the world, including New York, Berlin, Paris and southern and western American cities, showing how the various cities dispose of their sewage. The booklet contains 120 pages. It can scarcely be called a catalog as it is more of a treatise on the question of sanitation in the city.

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The Blast Furnace *and* Steel Plant

Pittsburgh, July, 1921.

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AGENCIES IN PRINCIPAL COUNTRIES THROUGHOUT THE WORLD